INJURY INCIDENCE AND SEVERITY IN PROFESSIONAL BALLET DANCERS OVER THREE YEARS

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A thesis submitted in fulfilment of the requirements of the University of Wolverhampton for the degree of Doctor of Philosophy

University of Wolverhampton
2014

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ACKNOWLEDGMENTS

I would like to express my sincere gratitude to all of those who made this project possible. As my Director of Studies, Prof Matt Wyon has helped steer this project from its inception to the final product. I would like to thank Professor Alan Nevill for both his patience and expertise. To Dr John Brooks, your experience and attention was invaluable. To Prof Bill Ribbans, thank you for your advice, opinion and painstaking proofing.

I would also like to thank my wife, Kate for her never ending support, and Francesca and Olivia, my motivation.

ABSTRACT

Although the benefits of exercise are well documented, the risk of injury as a result of exercise is also documented. The undertaking of exercise in the form of sport or dance carries a risk of injury. This risk is increased in the professional ranks where increased intensity of exercise coupled with greater exposure periods are noted.

Two published systematic reviews of the literature pertaining to musculoskeletal injuries and pain in dancers (up to 2008) indicated that there are still major scientific limitations and biases in the literature reviewed and indicated the need for explicit criteria on injury definition and methods of injury reporting. The reviews did comment on the evidence that musculoskeletal injury is an important issue for all dancers and that there is preliminary evidence that comprehensive injury prevention and management strategies may reduce injuries. The purpose of this single cohort observational study was to document injury incidence and severity in professional ballet dancers over three years including any changes as a result of changes within their medical management. While it is recognised that a randomised control trial would be advocated for an interventional study, due to the demands of this high performance environment this was not feasible. As such, steps were taken to improve the reporting of findings through the utilisation of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement. To date there are two publications in peer reviewed journals as a result of the data collected in this study.

In the absence of international consensus on injury data collection in dance the methodology employed in this study was consistent with the International Consensus Statements on injury data collection from sport. Although the incidence of injuries in Year 1 was lower than that in other sports, the results were higher than other studies that have been reported in dance. The reason for this may be due to the use of a more encompassing injury definition. In response to the data and details obtained through the injury audit process changes in the comprehensive medical management of the dancers were implemented. The pre-participation screening was extended and the individual conditioning programmes were structured using the developed Hybrid Intervention Model.

The result of the injury auditing indicated a significant reduction in injury incidence in the Year 2, with a further reduction in Year 3. These findings support the results of the systematic reviews in that there is growing evidence that comprehensive injury prevention and management strategies may reduce injuries in dance and that in the absence of stronger evidence there is a strong recommendation for those charged with caring for professional dancers to implement comprehensive medical management programmes.

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Chapter 1: Introduction

1.1 Dance Participation in the UK

Dance has played an important role in various societies as entertainment and expression since the times of ancient Egypt and Classical Greece. The modern day popularity of dance is also evident. From an audience perspective it is noted with 13% of the population in the United Kingdom is now attending dance performances, and the BBC's Strictly Come Dancing regularly being watched by 10.5 million viewers (Dance UK, 2010). There is also growth in dance participation (Arts Council, 2009). Dance is a generic term that covers a multitude of styles or genres. Classical ballet and contemporary or modern dance are the two dominant Western genres, but there are a number of other styles practiced and performed in the UK, including African, Ballroom, Bellydancing, Bharatha Natyam, Bodypopping, Breakdancing, Contact Improvisation, Flamenco, Historical / Period, Irish, Kalari, Kathak, Jazz, Jive, Latin American, Line Dancing, National and Folk, Raqs Sharqi, Salsa, Square Dancing, Street Dance, Tango and Tap (Dance UK, 2010). Dance UK indicate that there is a growing trend to dance among the UK population, quoting an 83% increase in the number of school pupils choosing dance in the last four years and research by the 'PE and School Sport Club links scheme' showing dance second only to football as the most popular activity of school children (Dance UK, 2010). The number of students taking GCSE dance has increased from 7,003 in 2001, 15,730 in 2005 to 18,866 in 2007 according to the Assessment and Qualifications Alliance (aqa.org 2009), and 1220 students graduated with degrees in dance in 2007/08 (HESA, 2009). Within the amateur and voluntary sectors there are over 3,000 dance groups, engaging 140,000 people (Arts Council, 2009). The total workforce of dancers within the UK is estimated at around 40,000 people, with teachers comprising the greatest proportion (Arts Council, 2009). Among the professional or elite ranks, Dance UK report that there are 3000 dancers registered in the UK (Dance UK, 2010).

1.2 The Benefits, Risks and Negative Impacts Associated with Dance Participation

The benefits of exercise related activities are numerous, wide ranging and well publicised. These include physiological benefits, by enhancing health and preventing disease, and psychological benefits by improving mood, self-esteem, psychomotor development, memory and calmness (Fentem, 1994). The health benefits of dance as a physical activity have also been recognised (Jain and Brown, 2001). Keogh et. al. (2009) provided a review and recommendation of the benefits of dance. The basis for recommendations was based on a grading system whereby a Grade B recommendation was based on support of at least one level 2 study (i.e. smaller randomised control study with less than 100 participants). A Grade C recommendation was based on support of at least level 3, 4, or 5 studies. Level 3 studies were nonrandomized, concurrent, cohort comparisons while level 4 studies were nonrandomized studies that compared older adults who received the intervention (i.e., were regular dancers) with those who were non-dancers and level 5 studies were case series or studies in which no control group was used. The authors provide a Grade B recommendation for benefits of dance based programmes that include aerobic power, muscle endurance of the lower extremities, muscle strength of the lower extremities, flexibilities of the lower extremities, static balance, dynamic balance and agility, gait speed, and a Grade C recommendation for increased bone-mineral content in the lower body, increased muscle power of the lower extremities, reduced falls rate and reduced cardiovascular health risk (Keogh et. al. 2009). As such the role of exercise, including dance, has been the focus of a government initiative to improve the health of the nation through its “Be Healthy, Be Active” initiative (Department of Health, 2009).

However it is recognised that participation in sport or dance can introduce a risk injury (Kujala, Taimela, Antti-Poika et. al., 1995; Parkkari, Kujala, and Kannus, 2001; van Mechelen, Hlobil, and Kemper, 1992). It has been estimated that the cost of athletic injury worldwide is around $1 billion (Murphy, Connolly, and Beynnon, 2003) with around 29 million injuries (new and recurrent) each year in the United Kingdom (Nicholl, Coleman, and Williams, 1995). These injuries can result in time away from exercise and their associated health and psychological benefits. The impact may extend to the workplace for those non-professional athletes or dancers where decreased productivity may occur through diminished capacity or complete absence in the workplace as a result of injuries incurred. The financial impact would extend to costs to the National Health Service and any post injury care needed for more serious injuries. Family and social life may also be disrupted by injuries due to the limitations placed on injured participants.

The negative impacts of injury to elite, professional athletes and dancers can be equally as high. The financial ramifications of injury range from the costs of medical care to loss of personal income through withdrawal from competition or performance. The time away from training and competition can lead to a performance deficit that could result in their withdrawal from funded programmes and impact on the team or Dance Company's performance. Future contracts may also be adversely affected by injury history and status. The potential of a longer term sequelae of injury also needs to be considered (Bahr and Holme, 2003). In football, 80% of retired footballers indicated joint pain during at least one activity of daily living (Drawer and Fuller, 2001), and 32%-49% reported being diagnosed with osteoarthritis (Drawer and Fuller, 2001; Turner, Barlow, and Heathcote-Elliott, 2000), which is higher than expected for their age equivalents in the general population (Drawer and Fuller, 2001). Similar concerns over long-term effects have been raised in dance, with evidence of a higher prevalence of osteoarthritis in dancers compared to age equivalent non-dancers in a study that measured radiographic findings of osteoarthrosis, including sclerosis, joint space narrowing, osteophytes, and subchondral cysts as part of the diagnostic criteria for osteoarthritis (Teitz and Kilcoyne, 1998). It is noteworthy that the level of evidence of these studies is lower with some results from the reporting responses via questionnaires, and this may be limited due to a number of confounding variables and biases, including a bias in respondents who have experienced some of the musculoskeletal problems being questioned as well as other methodological challenges to high level evidence. However in the absence of stronger evidence from the literature to the contrary, a strong recommendation that more attention needs to be paid to the long term sequelae of injury can be made. Furthermore the importance of reducing the injury burden on individuals, sport and dance organisations, as well as society as a whole, through increased focus on the incidence and aetiology of injury and potential strategies for its prevention could be advocated.

1.3 The Role of Sports Medicine in Mediating the Injury Impact

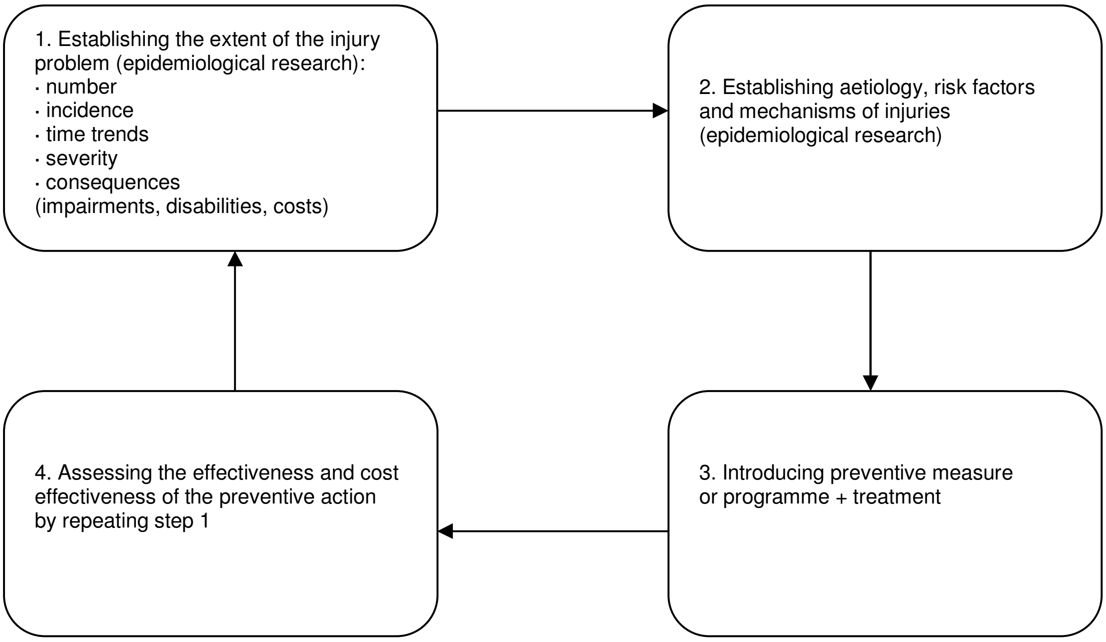
The role of sports medicine is well articulated in aims of the British Association of Sports and Exercise Medicine (BASEM), in promoting and studying methods for the protection and improvement of public health and fitness. BASEM also go on to include the promotion of research into causation and treatment of medical problems arising from sporting, recreational and other leisure-time activities (BASEM, 2010). The premise of injury prevention sits at the foundation of the aims set, with the promotion of research into causation providing the tools from which effective protection or injury prevention can be achieved. The information obtained via research can also be used to guide more effective treatment of injuries, with the effective management of the presenting injury along with strategic planning of future exercise based training may go some way into minimising the risk of developing secondary pathological changes as a result of injuries sustained.

Contrary to elite sport within the UK, where access to sports specific medical provision is possible, dance has not benefited from the specificity and support this level of service provision can supply. Despite the extensive history of dance, it was only in 1990 that the International Association for Dance Medicine and Science (IADMS) was created, bringing together a group of international dance medicine practitioners, educators, scientists and dancers to increase the understanding and service delivery for the well-being of dancers (IADMS 2009). Within the UK the dance industry has recognised the absence of an overall national body providing medical and science provision for dancers. This resulted in the formation of the National Institute of Dance Medicine and Science in April 2012 who has as one of their key objectives the establishment of a greater understanding of dance injuries.

1.4 The Role of Epidemiology and Injury Surveillance

In a model of injury prevention outlined by (van Mechelen, Hlobil and Kemper 1992) and further commented on by (Parkkari, et al., 2001) a 4-stage sequence of sports injury prevention is proposed (Figure 1.1). A fundamental component of this model arises from its first 2 phases of understanding the extent of the sports injury problem, including injury risk factors, through establishing its incidence and severity often via epidemiological research. This understanding is central to be able to target interventions in the prevention and management of relevant injuries in a sport (stage 3) (Meeuwisse, 1994; Orchard and Seward 2009). On-going surveillance can then test the effectiveness of the implementation of these strategies (stage 4).

Figure 1.1: Injury prevention model adapted from van Mechelen, et al. (1992)



Specifically the process of injury reporting via injury surveillance systems and epidemiological research may serve a number of functions (Meeuwisse and Love, 1997):

1. Estimating the burden of morbidity or mortality in population groups;
2. identifying risk factors and high risk groups;
3. safety decision making and allocation of healthcare and other resources;
4. an outcome measure for research on injury prediction; and
5. as the basis for assessing the effectiveness of interventional strategies designed for injury prevention.

Through epidemiological research in various sports, a greater understanding of incidence and aetiology has been acquired, leading to the implementation of specific intervention strategies and rule changes to reduce injury incidences. Lorentzon, Wedren and Pietilae (1988) used a prospective study to highlight the high incidence of facial lacerations in international ice hockey. Through their data collection, the authors were able to conclude that 47% of facial injuries would have been prevented by a visor. They also suggested that stricter enforcement of the rules were required. By using a prospective study over two consecutive seasons, Hagglund et. al. (2006) was able to confirm that previous injury is an important risk factor for injury in elite football, and the more injuries a player had sustained, the greater the risk of injury. The authors go on to indicate recurrent injuries account for some of the association between previous injury and the overall risk of injury. Further analysis suggests that previous hamstring, groin or knee injuries can represent a two to three fold increase in risk of the identical injury. As supportive evidence for improved medical intervention Hagglund et. al. (2006) also indicates that a relationship does not exist between previous injury and ankle sprains, and alludes to advances in ankle rehabilitation being far better understood and implemented, as opposed to other injury sites, as the reason for the prevention of recurrent ankle sprains. The authors conclude that secondary prevention of recurrence is a key point in reducing the overall incidence of injuries. Similarly, Fuller, Brooks and Kemp (2007), when looking at spinal injuries in professional rugby union, use a prospective study to identify players that were exposed to spinal injuries during tackling and contact rugby skills sessions, as well as weight training sessions. Using this information, the authors are able to provide recommendations as to where preventative strategies may benefit players at risk of spinal injuries. Whilst these papers are able to use the data from one or two years to provide recommendations as to where preventative strategies may lie, the Australian Football League has been the subject of a longstanding injury surveillance study (Orchard and Seward 2009). As a result of their injury surveillance system, the authors are able to confirm the impact of a change-in-rules to the incidence rates of posterior cruciate ligament injures, giving a direct example of how injury surveillance can be used to implement change to extrinsic risk factors. Intrinsic factors have also been influenced through their injury surveillance, with data on hamstring injuries suggesting a more conservative approach to their management in 2008, possible due to research indicating that recurrence rates remain high for many weeks after initial injury.

1.5 Risk Assessment and Management

It is important to understand the injury profile and risks to professional athletes to help reduce the negative injury impacts and enhance their performance capacity. In addition there is an ethical consideration to preserve and promote health on the long term. There is also a legal obligation to report injuries to professional athletes (Fuller, 1995).The Health and Safety Executive in the UK provide guidelines for health and safety requirements within UK industry. Within those guidelines, there is a legal obligation for the risks of injury within the workplace to be controlled by the employer via risk assessment (Health and Safety Executive 2009). Although the process of risk assessment and risk management may be commonplace within other occupational environments, its implementation within sport has not always received the same amount of attention (Fuller and Drawer 2004). Risk assessment, which involves the identification, estimation and evaluation of risks, can be used to identify "at risk" activities within sport (Fuller and Drawer, 2004). Fuller and Drawer (2004) explain that in isolation this does not lead to a reduction to levels of injury and that it needs to be placed in the context of risk management, which is defined as "the overall process of assessing and controlling risks within an organisation". The first stage of risk assessment and risk management is the identification of risk factors (Fuller and Drawer, 2004) most effectively as part of epidemiological research.

1.6 Injury Risk Factor Identification

Sporting risk factors have been defined by many authors. Hershman (1984) states that "risk factors for a particular sport are derived by combining the epidemiology of injuries for a particular sport and the predisposing conditions that may lead to injury". Although this provides a global view towards injury risk identification, there is a need to provide greater specificity to the predisposing conditions. Fuller and Drawer (2004) indicate where risk factors can be further delineated to allow a greater degree of specificity to the athlete and their needs by defining an injury risk factor as "a condition, object or situation that may be a potential source of harm to people" and risk as "the probability or likelihood that a risk factor will have an impact on these people". Risk factors can be categorised as intrinsic or extrinsic (Fuller and Drawer, 2004, Bahr and Holme, 2003, van Mechelen et. al., 1992, Meeuwisse, 1991). Intrinsic factors are considered to be those specific to an individual participant, and can include age, strength and joint stability, whereas extrinsic factors arise from external sources, and would include surfaces, protective equipment and laws of the game (Fuller and Drawer, 2004). Risk factors can also be divided into modifiable and non-modifiable (Bahr and Holme, 2003). Modifiable risk factors, like strength and flexibility can be altered through training, unlike non-modifiable aspects, like gender and age (Bahr and Holme, 2003). Although the non-modifiable factors may not be altered they can still be used to predict potential risk and mediate further injury. One such risk factor in dance that could be considered non-modifiable could be the presence of benign hypermobility joint syndrome. It has been demonstrated that a higher prevalence of this often hereditary disorder occurs in vocational ballet dancers and the lower ranks of professional ballet companies compared with a matched non-dancing population with an Odds Ratio of 11.0. Whilst there is no cure for this musculoskeletal disorder associated with increased elasticity, by being aware of its presence, increased measures may be taken to control factors that in combination with the increased collagen elasticity may predispose to injury (Briggs, McCormack, Hakim et. al. 2009; McCormack, Briggs, Hakim, et. al 2004).

In a theoretical model describing the causation of injury, Meeuwisse (1994) suggests that it is the intrinsic factors that predispose athletes to injury, but they seldom lead to an injury alone, and it is the combination of both intrinsic and extrinsic factors that can leave an athlete susceptible to injury (Figure 1.2). Meeuwisse (1994) also indicates that “an inciting event” provides the final variable in the injury causation model. Bahr and Holmes (2003) suggest expanding the model, arguing the inciting event would often only constitute the mechanism of injury, but fail to document the events leading up to the injury and suggest that this information can be more important in understanding causation (Figure 1.3).

Figure 1.2: Multifactorial Model of Athletic Injury Etiology

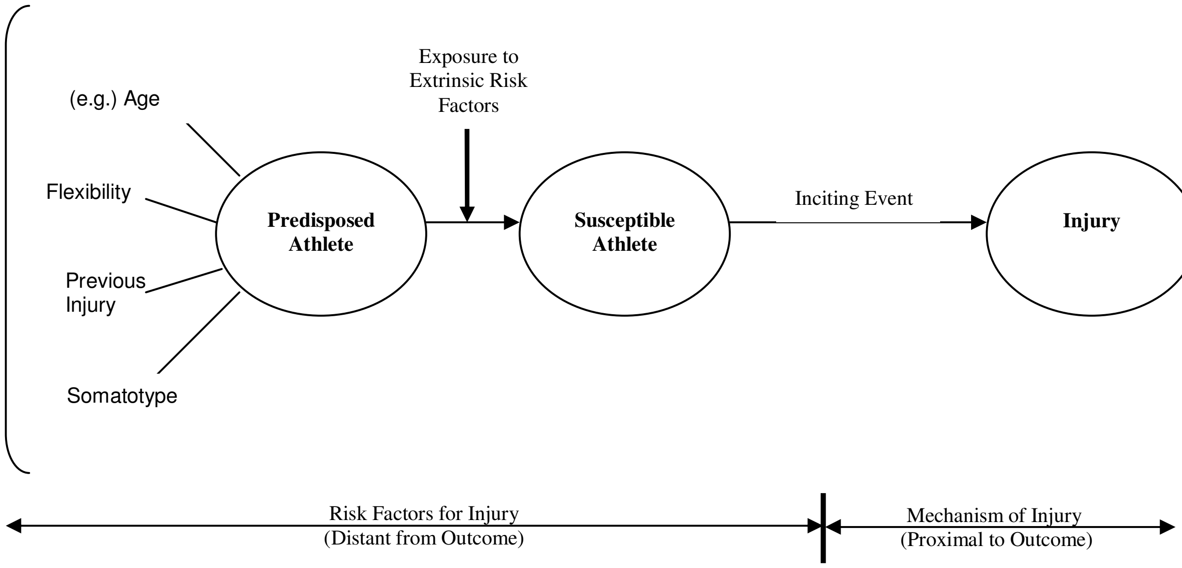
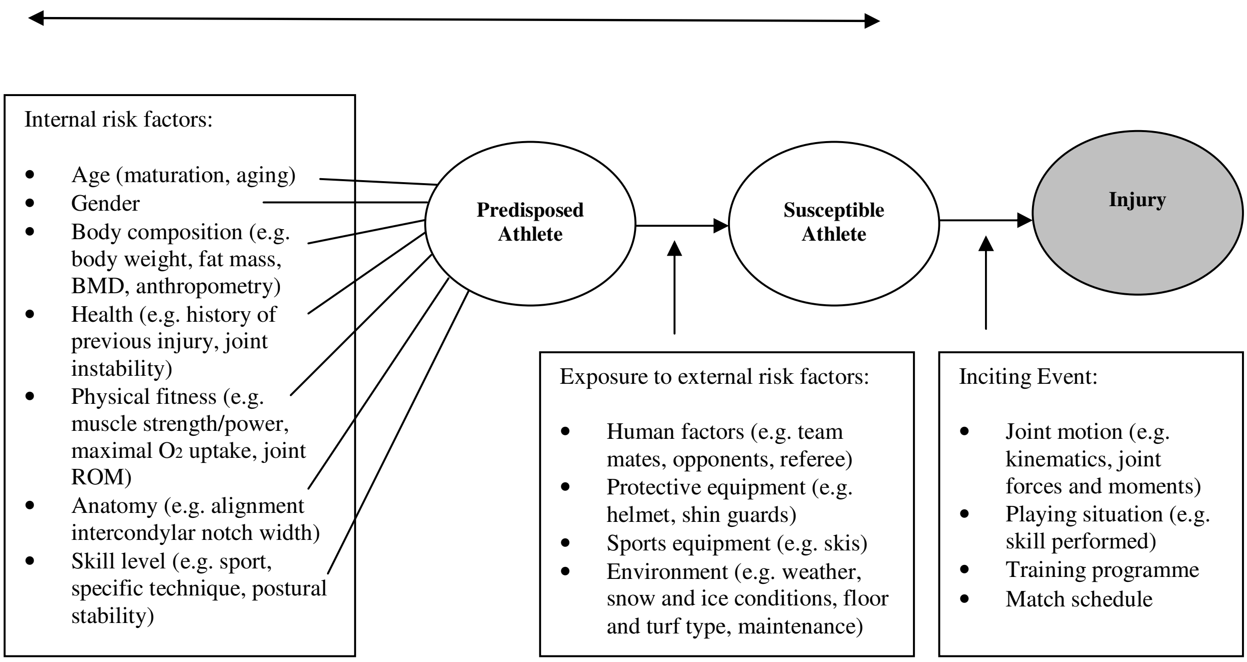
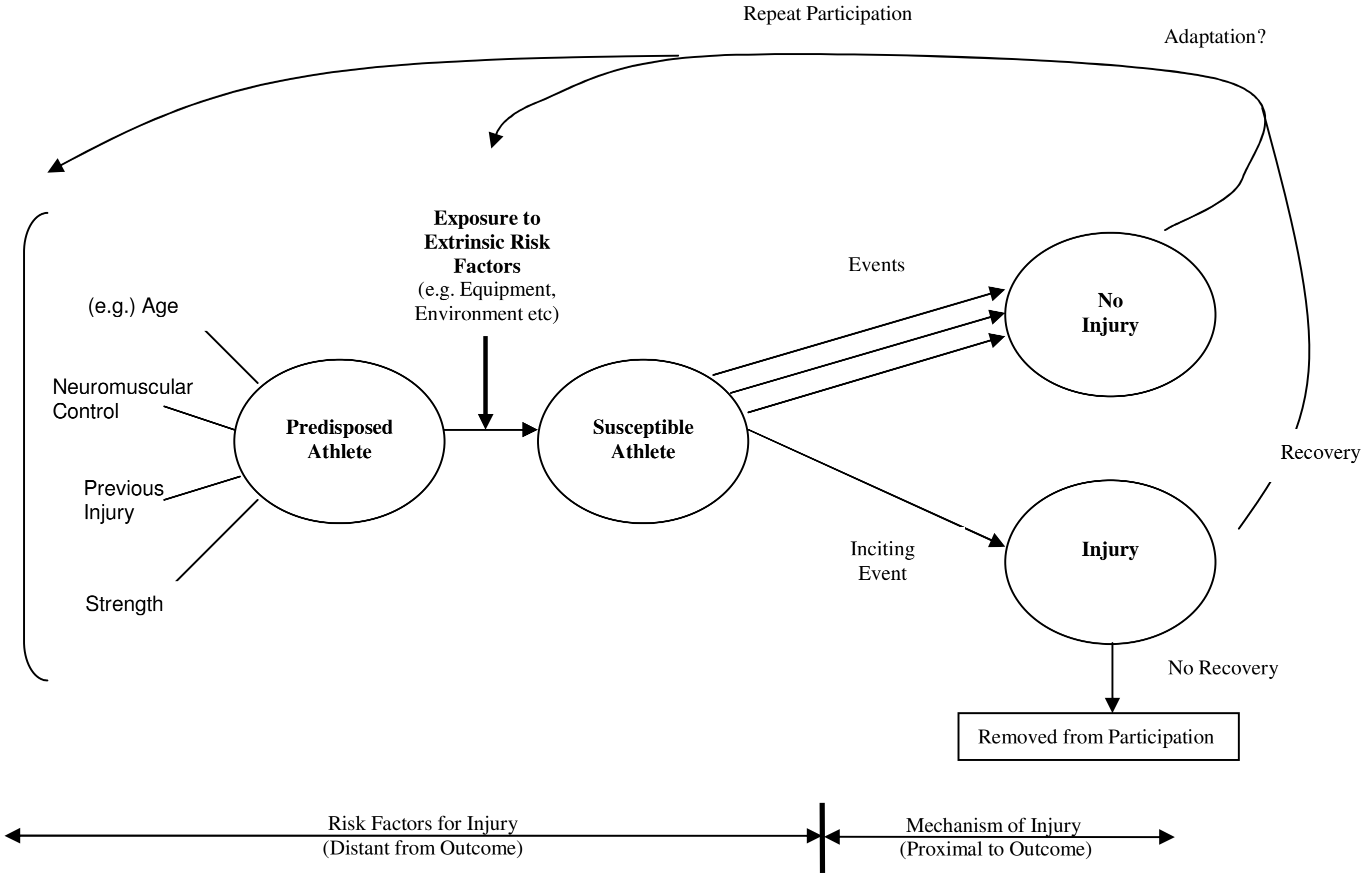


Figure 1.3: A Dynamic Multifactorial Model of Sport Injury Etiology



These earlier models have since been dismissed as linear paradigms that show a sequential event time line from the beginning point to an end point, in favour of a more dynamic model allowing for a recursive nature of risk and causation to be considered (Meeuwisse et al., 2007) (Figure 1.4). Part of the basis for their recursive nature theory includes that in most cases the presence or occurrence of injury does not permanently remove that said athlete from participation and therefore does not represent a finite end point.

Figure 1.4: A Dynamic, Recursive Model of Etiology in Sport Injury



The original model by Meeuwisse (1994) provides an excellent foundation from which injury causation can be explored, and fits in well into stage 2 of the injury prevention model proposed by van Mechelen, et al. (1992). The expansion of the inciting event by Bahr and Holme (2003) provided a further insight into the dynamic nature of injury causation, emphasising that a multitude of risk factors may be involved in injury causation, including position within the playing area and skill, rather than just biomechanical principals directly around the injury incident. While it is recognised that the key in injury causation may arise from the inciting event, influenced by the interaction of intrinsic and extrinsic factors, this needs to capture the dynamic and variable nature of this interaction based on situational exposure, where changes in one extrinsic factor may lead to a different interaction with an intrinsic factor and result in the causation of a new/different injury. An example of this could be with the interaction of intrinsic factors of hip and ankle range of movement, and the extrinsic factor of playing surface or theatre stage. Limited range of movement at hips and ankles has been linked to injury in some sports (Dennis, Finch, McIntosh, et. al., 2008). Within dance, the presence of a limitation or control of hip range of movement may also predispose the dancer to injuries of the back, knee and lower extremities including sartorial and piriformis tendonitis, anterior knee pain, patella femoral dysfunction, anterior impingement syndrome of the ankle, plantar fasciitis, and metatarsal stress fractures, (Bennell, Khan, Matthews, et. al. 2001; Coplan 2002, Russell 1991). The limitation of hip and ankle range of movement may also result in a restriction in jump height (Bennell, et al., 2001). This in the presence of a performance stage that has poorer force reduction properties, may result in decreased ground reaction forces experienced by that dancer, reducing the possibility of injury in that instance, whereas a dancer with a greater hip and ankle range of movement, allowing a greater jump height, may on the poorer surface, become more susceptible to the impact and increased ground reaction forces, resulting in the increase risk of injury. The interaction of these intrinsic and extrinsic factors may also be influenced by the overall exposure, where dancers may be at the end of a touring period when they encounter the stage with the poorer force reduction properties, and so through overall fatigue, reduce the dancers potential ability to withstand this new interaction of risk factors. This is reflected in Bahr and Holme's

(2003) example of an overuse injury and need to allow for the longitudinal nature of the inciting event. The recursive model proposed by Meeuwisse et. al. (2007) may allow this dynamic process to be better evaluated as it allows for the athlete or dancer to continue within the exposure period and not necessarily remove them from the intrinsic/extrinsic interaction. This multi-factorial nature of injury causation would require multivariate analysis, where these interactions could be explored. For this to occur, larger cohort numbers would be required (Meeuwisse, 1994). The use of prospective cohort design studies will provide important information for the injury causation model, where information can be gained regarding potential predisposing factors for athletes or dancers who do not go on to sustain injuries. This, along with evaluating the impact of interventional strategies, will enhance the overall understanding of injury causation and provide more information for our injury prevention strategies.

1.7 Epidemiology Methodological Considerations

The model proposed for injury prevention has at its foundation the establishing of the extent of the injury problem, including numbers, incidence, time trends, severity and consequence of injury, as well as establishing the aetiology, risk factors and mechanism of injuries (van Mechelen, et al. 1992). The means for collecting this data is via injury surveillance or epidemiological studies. "Injury surveillance", defined as the on-going collection of injury data (Pakkari et. al. 2001), can constitute a number of approaches, but the relevance of the data is largely influenced by the validity and reliability of the definitions of sports injury, severity and exposure (Finch, 1997). It is also recognised that, whilst it may be ideal to use the same systems of injury surveillance for all sports, the specificity of different sporting environments needs to be recognised and possibly reflected in the method adopted (Pakkari et. al. 2001). This is supported by Hodgson-Phillips (2000), who indicates comparing injury statistics across sports may be invalid due to the number of intervening variables. But, the more those variables are aligned the more convergent view we may obtain both within a specific sport as well as across sports. As such, there has been an increased focus within sports epidemiological literature to both challenge and provide consensus statements to those methodological variables. A consensus approach to injury surveillance will provide additional benefit from those sports or athletic pursuits like dance that have not benefited from the same level of attention as better funded sports like football and the rugby codes, where more epidemiological studies have been undertaken. A number of larger national bodies have employed epidemiological studies as part of their accountability to their members and the organisation, providing a valuable tool in determining patterns and trends specific to their needs and offering the capacity to interpret results of changes made (Brooks, Fuller, Kemp, et. al. 2005; Brooks, Fuller, Kemp, et. al. 2005a, 2005b; Chalmers, 1994; Dick, Agel, & Marshall, 2007; Fuller, Hawkins, Dent, et. al.1997; Hawkins and Fuller, 1999; Orchard, 2008; Simpson, Chalmers, Waller, et. al. 1994; Waller, Feehan, Marshall, et. al. 1994). One of the longer running studies evaluates the impact of injury in Australian Rules Football, and as a direct result of data collect, rule changes have been made and re-evaluation has demonstrated a decrease in the original identified problem (Orchard and Seward, 2009; Orchard and Seward, 2002). At present there is no over-riding governing body for dance in the United Kingdom, with no long-term epidemiological studies being undertaken, the understanding and knowledge of injury incidences and the impact of those injuries on the United Kingdom dance community is therefore affected.

While it is clear that injury surveillance and epidemiological studies can yield valuable information to aid the management and treatment of sports injuries, the validity, and therefore the usefulness of the results are dependent on the use of an appropriate design and methodology. Consistency in study design and methodology can also aid the ability to compare studies both within sports and between sports.

1.7.1 Study Design

There are two main approaches to study design in sport (Meeuwisse and Love, 1997). Firstly case series design where injury specific case findings (Lundon, Melcher, and Bray, 1999; Menetrey and Fritschy, 1999; Miyamoto, Dhotar, Rose, et. al. 2009), or sport specific case series (Quirk, 1983; Vann and Manoli, 2010) or population or institutional based case series (Cuff, Loud, and O'Riordan, 2010) are analysed. The main issue with a case series study design is that data collection is restricted to injured athletes alone and does not include information of the non-injured athletes, limiting the ability to verify a study's conclusions (Hodgson-Phillips, 2000). In addition, case series studies lack data on the exposure of the participants to injury (Meeuwisse and Love, 1997). The second method of study is a cohort design, which allows for analysis between injured and non-injured athletes. Due to its analytical nature, it not only allows the measurement of injury rates, but allows an estimation of injury risk to be considered. The ability to differentiate between the characteristics of injured and non-injured athletes is a key benefit in cohort design studies as it allows a means to test assumptions over causative factors in injury. This may be of particular use in dance in order to further develop the understanding of risk factors for this complex group of performance athletes.

1.7.1.1 Prospective and Retrospective Research Designs

As part of the research design process, injuries may be collected retrospectively or prospectively (van Mechelen, et al., 1992). The use of retrospective design studies has been noted in dance (Bowling, 1989; Brinson and Dick, 1996; Chmelar, Fitt, Schultz, Ruhling, et. al. 1987; Evans, Evans, and Carvajal, 1996; Laws, 2003, 2005; Ramal and Moritz, 1994; Sohl and Bowling, 1990). Major flaws can exist with the use of retrospective designs, among them are issues of recall bias and over (or under) estimation of exposure affecting the validity of the results (van Mechelen, et al., 1992). Gabbe, Finch, Bennel, et. al. (2003) has indicated a failure in athletes' ability to recall injury history over a 12 month period. The use of prospective study designs can improve both the validity and reliability of research findings, and therefore provide greater confidence in the findings upon which interventional strategies may be based as part of the objective of reducing the impact of injuries.

1.7.2 Injury Definition

A key factor in the design of an injury surveillance or epidemiological study is the definition of injury used, because it has a major impact on the nature, validity and comparability of the data collected. Within sports and dance epidemiology literature to date, a number of definitions have been used:

- physical damage via a sports or dance related incident irrespective of its result in incapacitating the participant (Ramal and Moritz, 1994; Ramal, Moritz, and Jarnlo, 1996),
- injuries requiring hospital treatment (Hoy, Lindblad, Terkelsen, et. al. 1992; Jones and Taggart, 1994; Lindblad, Hoy, Terkelsen et. al. 1992; Quirk, 1983);
- injuries requiring referral for treatment or medical attention/medical records (Gabbett, 2003; Nilsson, Leanderson, Wykman, et. al. 2001; Phillips, Standen, and Batt, 1998; Solomon, Micheli, Solomon, et. al. 1995)
- injuries resulting in a claim against an insurance policy (Bronner, Ojofeitimi, and Rose, 2003; Solomon, et al., 1995; Solomon, Micheli, Solomon, et. al. 1996; Solomon, Solomon, Micheli et. al. 1999)
- those that result in an inability to compete or practice as planned (Brooks, et al., 2005; Hawkins and Fuller, 1999)
- or those causing time loss from sports matches/competition (Orchard and Seward, 2009).

Although a number of factors may influence the choice of injury definition used, like finance, human resources, and accessibility to patient groups, the choice of injury definition should be determined by the underlying objective of the research paper, for example, a study investigating the financial cost of injury may utilise insurance claims forms as an indicator of injury (Bronner, Ojofeitimi and Rose 2003; Solomon, et al. 1999), while a study investigating the impact of sports injury on hospital services may utilise hospital attendance as an injury definition (Jones and Taggart, 1994). Although serving the purpose of answering their intended research question, there are limitations as to the external validity of some of these definitions. The use of an injury definition that includes physical damage via a sports or dance related incident irrespective of its result in incapacitating the participant may not truly reflect the impact of the injury on performance with potential for over-reporting of incidents where patients utilise therapy services for maintenance purposes. In sports (or the few dance) organisations with "free to the user" and accessible medical care in-house, this may be more prevalent. These injuries would be difficult to document and classify for injury audit purposes, as well as analyse as part of a strategy to reduce the impact of injuries. The use of attendance at hospitals or claims against insurance policies could result in an under-reporting of injuries where only the more severe injuries are documented. Similarly the use of medical records could also result in some more minor injuries that still affect performance or contribute to the long term sequelae of injury being missed. This may be relevant in dance where medical provision for a large number of dancers is not always provided and as such access to medical personal/care would incur personal financial implications, which may result in dancers failing to report to medical personal, opting to either continue in an injured state, or attempt self-management of their condition.

Some studies employ a time loss definition where only injuries that result in missing a planned session are recorded (Harringe, Renstrom, and Werner, 2007; Orchard and Seward, 2002; Shrier, Meeuwisse, Matheson, et al. 2009). It has been suggested that time loss from matches (in team sports), represents the cheapest, most functional, most accurate and only time loss system that can reliably capture 100% or close to 100% of the defined data (Orchard and Hoskins, 2007). Despite advocating this definition, Orchard and Hoskins (2007) indicate some of its limitations as: its use in the sports where competition occurs rarely; the strong bias seen against injury occurring is the last match of the season; the threshold for reporting is biased when matches may deviate from a standard schedule (e.g. 1 game per week); those injuries not identified through the use of analgesics/anaesthetics by players to continue to perform; and failure to capture injuries that still constitute a financial impact but may not constitute a missed match. Further limitations of this system is that it has the potential to fail to capture those injuries that may play a relevant role in the sequelae of another (potentially more serious) injury and that impact on performance without missing any planned activities (Lüthje, Nurmi, Kataja, et al., 1996). The nature of dance would make this definition less appropriate, where there is not the uniform scheduling of competition. Dance performances may be sporadic or occur in performance blocks of 2 to 6 weeks, followed by a number of weeks in rehearsals. The use of missed performances may result in a large number of injuries being missed as they could have resolved within the time elapsing between performance periods. The nature of dance also means a dancer may be unable to perform a more challenging role due to an injury but may be able to undertake a less challenging role. Using this time loss system these would not be classified as injuries, whereas they are unable to perform to the full capacity and undoubtedly have an injury. The nature of dance rehearsals may introduce a potential risk of injury, with longer hours spent repeating "new" movement sequences, and so needs to be accounted for within the overall understanding of injuries in dance. It is suggested that those studies that use an all-encompassing time loss injury definition that includes injuries causing time loss in training as well as missed matches, will enable a true global picture of injury incidence in sport to be obtained (Hodgson et. al. 2007), although reporting reliability can be difficult (Orchard and Hoskins, 2007). Using restricted activity definitions, the distinction between partial and complete restrictions is not always made which may result in the seriousness of the injury not being fully appreciated (Fuller, Bahr, Dick, et. al. 2007), although this can be partially overcome by reporting injury severity (Brooks and Fuller, 2006). By using a time loss injury definition in dance that accounted for restricted activities, it would provide an opportunity to explore those injuries that affect performance and such have consequence to all stakeholders as well as provide a basis for strategic planning for a company wishing to invest in their dancers' health and well-being. Capturing data on injuries that resulted in complete absence from dance activities as well as restricted activities could offer an even greater understanding of the impact of injuries on performance.

Consensus statements on injury definitions have been published for football, rugby union and tennis. Injury definitions have ranged from physical complaints and exceeding the body's functional integrity to medical attention and time loss in football and rugby (Fuller, Ekstrand, Junge, et al. 2006; Fuller, Molloy, Bagate, et al. 2007) while tennis expanded the injury definition into "medical conditions" to include both illness and psychological aspects as well as injury (Pluim, Fuller, Batt, et al. 2009). The value to a consensus statement comes from the process of key researchers and clinicians within the field/sport discussing and agreeing on the best process for the development of epidemiological data within their field. In providing a consensus statement, it offers a template for other researchers to base their work, allowing a greater possibility for cross-study comparisons. This process of reaching (and using) consensus definitions has also been recognised in dance (Bronner, Ojofeitimi, and Mayers, 2006; Liederbach and Richardson, 2007, Leiderbach et. al. 2012). As recognised by the tennis consensus statement, there is a need to both adopt and utilise aspects of the established consensus documents that have been able to demonstrate the value to this process in assimilating valuable data for their disciplines, but there is also a need to incorporate more specific aspects that would have more direct relevance to that particular sport/activity. Within dance, the nature of the non-competitive environment in relation to sports, where performances are objectively measure by times, heights, points and goals, could mean that a dancer can alter or reduce their maximum performance capacity to accommodate an injury and yet continue to perform. As such it is imperative within the dance environment that an all-encompassing time loss injury definition is used to allow those injuries that can affect performance but not necessarily result in full withdrawal from dance related activities to be accounted for.

1.7.3 Data Collection and Reporting

Further influences on the validity of results of injury surveillance studies stem from the reporting of injuries. The three most common ways of reporting injuries are by using absolute injury numbers, the proportion of injuries and the injury incidence (Brooks and Fuller, 2006). Results presented as numbers or proportions offer limited value due to the exclusion of exposure data due to the inability to ascertain activity periods/exposure as to when athletes may be at risk of injury and cannot be compared to other papers due to variations in number of injuries (Hodgson Phillips 2000; Brooks and Fuller, 2006). Incidence, however, as a mathematical and epidemiological term, is a ratio where the inclusion of a defined population at risk as well as the time at risk is included (de Loes, 1997). Even with exposure recorded, the number of ways in which incidence can be expressed can challenge inter-study comparisons. Common methods for displaying incidence with exposure includes injuries/1000 player hours of exposure (Hawkins and Fuller, 1999), injuries/1000 athlete exposures (Meeuwisse and Love, 1997) and injuries/1000 match hours (Hägglund, Waldén, and Ekstrand, 2006). By expressing injury incidence as a component of 1000 hours exposure it allows cross comparison to other recognised sports epidemiological papers (de Loes, 1997) as well as allow a better understanding of potential risk. Within dance, there is a potential for dancers to undertake lengthy or prolonged periods in dance related activities and therefore the need to account for exposure is critical in determining potential risk in dance.

1.7.3.1 Exposure and Denominator Data

It is recognised that the literature on injuries in dance is weakened by inconsistent exposure techniques (Liederbach and Richardson, 2007). Exposure can be expressed by two means, as activity based units (athletic exposures (AE) or time based units (Bronner, et al. 2006). The use of athletic exposures, where 1AE is calculated as participation in one practice or competition session (Dick, et al. 2007), has been used by the National Collegiate Athletic Association Injury Surveillance System's in reporting over a number of sports (Agel, Olson, Dick et al., 2007; Agel, Palmieri, Dick, et. al. 2007; Dick , Hertel, Agel, et. al. 2007; Dick, Hootman, Agel, et. al. 2007; Dick, Sauers, Agel, et. al. 2007; Marshall, Covassin, Dick, et. al. 2007). A major limitation to the use of athletic exposures as a measurement of exposure is the variation in time that each session may have. Competition in some sports may only constitute ten seconds (in track athletes), to a number of days (in test cricket). Similarly, training session times may also vary considerably. This would make cross comparisons between sports invalid. The second means of capturing exposure is using time based units. This system allows for greater understanding as to the level of exposure that athletes have had and as such would appear favourable to provide a greater insight in predicting risk. In dance due to the variations in length of rehearsals, dance class and performances, calculating exposure as a component of time using a ratio per 1000 hours would be more sensitive.

A limitation of both systems is that they fail to incorporate the intensity of the exposure session. It is recognised that dance may also present certain challenges to measuring exposure as the nature of dance related activities can vary in regards to energy exposure due to the nature of the different dance related activities (O'Mailia, Scharff-Olson, and Williford, 2002). Although individually calculated exposures for dancers would be ideal, it is recognised that in large ballet companies, individual dancers schedules of rehearsals and performances may be too time consuming and that average exposure calculation based on group data is an acceptable method (Bronner, et al., 2006).While the measurement of energy exposure during dance related activities would provide an even greater understanding of the exposure, and subsequent risk to a dancer, its use during longitudinal epidemiological studies has substantial practical issues making its incorporation problematic and potentially prohibitive.

1.7.4 Reporting the Severity of Injuries

The severity of injuries sustained, along with injury incidence constitutes key parameters in epidemiological studies as they allow both the ability to define the magnitude of an injury problem in a specific population group as well as allowing intra and inter-sport comparisons of the data to be considered. It also enables the relationship between risk and injury to be considered and provides the evidence to assess the effectiveness of implemented interventional strategies (van Mechelen et. al. 1992). Brooks and Fuller (2006) reflect this importance of injury definition and severity, indicating that the variations often challenge any validity of inter-study comparisons. The inclusion of injury distribution and nature can provide further data to an overall risk analysis. Severity in dance studies is paramount as the potential for higher rates of more minor injuries might mislead health care providers as to the relative risks associated in dance.

1.7.5 The Distribution, Nature and Coding of Injuries

The use of standardised diagnosis coding systems can improve inter-tester reliability as well as reduce the subjectivity (Hodgson-Phillips 2000). The Orchard Codes System is one system that is used within sports injury studies (Brooks, et al., 2005, Fuller, Brooks, and Kemp, 2007). The need for coding of injuries in dance has been recognised (Bronner, et al., 2006), and in using an international recognised coding system, it can improve the cross-comparative ability of papers along with improving reliability of outcomes.

1.7.6 Sample Size and Study Length

The influence of sample size on the validity of outcomes is usually expressed as the studies power. The power of a study is defined as "its ability to demonstrate that there is an association between a risk factor and injury, given that the association exists" (Bahr and Holme 2003). Bahr and Holme (2003) indicate that if greater confidence in an effect is required, a greater sample size is required. Access to larger groups of participants in dance may be difficult due to the lack of a central governing body to co-ordinate larger scale studies effectively.

1.8 Summary

The reasons for undertaking injury surveillance can differ. The challenge lies in ensuring the validity of the results. Among those variables are issues of design, definitions and methodologies. It is by acknowledging and accounting for these variables that we are able to enhance the validity of outcomes, and as such enhance our ability to facilitate risk assessment and risk management. Risks are usually categorised as of extrinsic and intrinsic origin. A fundamental component of comprehensive risk assessment is the establishment of injury causation. The nature of injury causation models has certainly evolved and developed and contributes to the necessity to impose conformity and rigor to the methodology applied when looking at injury incidence.

Considerable discussion has centred on definition of injury used in injury surveillance studies. Within elite sport or dance, the overall outcome criteria are based on performance rather than by participation. To this, a definition that allows for the appreciation of those injuries that affect optimal performance, i.e. restricted activity injuries, but not necessarily constitute time loss, may potentially allow an even greater understanding of those minor injuries that could possibly progress to a more clinically severe presentation, or influence the onset of a further injury, but ultimately effect the participant from performing optimally. By classifying severity, it will enable data to be collected to indicate the time period whereby the restriction of activity has been present. Using severity, risk may be calculated, which may form an important part of understanding injuries in dance, as the lack of more severe injuries may mislead healthcare providers as to the potential risks associated with dance.

The way in which injuries are reported is also subject to a number of options, with injury incidence generally advocated. Exposure ideally should be individually calculated, but it is accepted that this may take the form of estimated exposure. Favouring a time related exposure definition in dance would allow accumulated exposure to be better appreciated. Once injury is defined and exposure calculated, the magnitude of risk can be better appreciated by including severity. In order to develop interventional strategies to reduce injury incidence, inclusion of injury distribution and injury nature need to be included. This can be further validated by the use of standardised diagnosis coding systems. It is also important to balance the objectives set in regards to assessing the relationship between risk factors and injuries against sample size, to ensure that if greater confidence in the relationship is needed, a greater sample size is considered. With access to larger cohorts of dancers problematic, the use of longer term epidemiological studies may provide greater numbers to enhance the power of outcomes.

Evidence within the sporting literature exists that suitably demonstrates that when design, definition and methodological variables are considered, outcome measures can give important information to stakeholders as to the risks associated with particular sports. As the objectives of healthcare providers within dance reflect those of the healthcare providers in sport in reducing the impact of injuries and offering an ability for participants to compete at an optimal level of function, similar steps needs to be taken into creating a greater understanding of the risks associated with dance participation, through the incidence and severity of injuries, as well as potential strategies that may be employed to reduce those factors.

1.9 Conclusion

The role of sports medicine has been described as providing protection and improvement of public health and fitness. A key component of the injury prevention model arises from understanding the extent of the injury problem, established through the use of injury surveillance and epidemiological studies. Well-structured designs have the ability to provide valuable information as to the level of risk within a sporting environment. It also can provide the comparator for the impact of applied intervention strategies and as such should be the focus of healthcare providers charged with the duty of caring for these special population groups like dance.

1.10 Further Chapters

This chapter looked to explore the issues surrounding risk identification in dance and how the use of epidemiological studies may provide a system to evaluate the impact of exercise related activities in injury incidence. The methodological challenges of designing an appropriate injury surveillance system was explored in relation to the validity of the results obtained. This information will be used in conjunction with literature pertaining to musculoskeletal injury and pain in dancers (Chapter 2). Using this background understanding of injuries in dance and injury surveillance, a single cohort observational injury surveillance study was undertaken with the purpose to document injury incidence and severity in professional ballet dancers over three years including any changes as a result of changes within their medical management. The results of the first year will be presented in Chapter 3. As a result of the data obtained in Year 1, changes to the medical management of the dancers were observed, including changes to the pre-participation screen and the design of individual intervention programmes (Chapter 4). This is followed by a comparison between the injury results of the first years (Year 1) data with the subsequent two years (Year 2 and 3) (Chapter 5). An overall discussion (Chapter 6) and conclusion (Chapter 7) will be presented, along with any limitations and recommendation for further research (Chapter 8).

1.11 Thesis Null Hypotheses:

The following null hypotheses were proposed in relation to this thesis.

Chapter 3

1. There will be no significant differences in injury incidence in respect to gender
2. There will be no significant differences in injury incidence in respect to rank
3. There will be no significant differences in injury incidence in respect to injury episode
4. There will be no significant differences in injury incidence in respect to injury type

Chapter 4:

1. There will be no significant differences in screening scores as a result of changes to the comprehensive medical management programme

Chapter 5:

1. There will be no significant differences in overall injury incidence as a result of changes to the comprehensive medical management programme.
2. There will be no significant differences in injury incidence in respect to gender as a result of changes to the comprehensive medical management programme.
3. There will be no significant differences in injury incidence in respect to rank as a result of changes to the comprehensive medical management programme.
4. There will be no significant differences in injury incidence in respect to injury episode as a result of changes to the comprehensive medical management programme.
5. There will be no significant differences in injury incidence in respect to injury type as a result of changes to the comprehensive medical management programme.

Chapter 2: Systematic Review

2.1 Introduction

In Chapter 1 it was indicated that dance participation, like sport, can entail a degree of risk. Part of the responsibility of those charged with caring for dancers is to mitigate that risk. Some of this may be achieved through the prevention of injuries. An injury prevention model presented by van Mechelen et. al. (1992) and introduced in Chapter 1 uses a four stage approach to injury prevention, the first stage and starting point of which is achieved through understanding the extent of the injury problem. One means to explore the extent of the injury problem is through a systematic review of the literature.

To date two systematic reviews (Hincapie et. al. 2008, Jacobs et. al. 2012) pertaining to musculoskeletal injuries and pain in dancers have been published. The first in 2008 was designed to assemble and synthesize the epidemiology, diagnosis, prognosis, treatment and prevention of musculoskeletal injuries and pain in the dancing population up to October 2004 (Hincapie et. al. 2008). Through the application of a priori criteria 32 articles were accepted for review and underwent appraisal to determine scientific merit and clinical relevance using an electronic critical review form. The authors comment that 69% of the articles identified from the titles and abstracts were consequently not accepted following full text review due to being scientifically inadmissible, citing reasons including: small case series; inappropriate study design in relation to the research question; vague case definition; insufficient information regarding the source population, the at risk population, or sampling methods; or involved unrepresentative, highly selected study populations. Of the studies accepted Hincapie et. al. (2008) indicates the literature has many limitations resulting in difficulty on drawing consistent conclusions. The limitations include: the variety of injury definitions used; the heterogeneous nature of the populations; failure to identify the population at risk that should form the denominator in incidence (or prevalence) calculations; and the wide range of inclusion and exclusion criteria. Hincapie et. al (2008) does offer some important conclusions despite these limitations, including that there is evidence that musculoskeletal injury is an important issue for all dancers and that there is preliminary evidence that comprehensive injury prevention and management strategies may reduce injuries. In a follow-up to the original

Hincapie et. al. (2008) review Jacobs et. al. (2012) extends the review period from October 2004 to March 2008. Repeating their methodology the authors reviewed a further 19 articles that were deemed scientifically admissible (with similar reasons for exclusion noted as per their previous review). The authors comment on an increase in the percentage of admissible studies rising to 68% compared to the 31% admissible studies noted in the previous review. Jacobs (2012) still reiterates the need for explicit criteria on injury definition and methods of injury reporting and comment that there are still major scientific limitations and biases in the literature reviewed.

What these two systematic reviews demonstrate is that there is an importance in evaluating the evidence of musculoskeletal injuries and pain in dancers and that due to an increasing emphasis on scientific rigor in dance medicine related articles an up-to-date position needs to be established. In addition, guidelines and recommendations based on the evidence needs to be established that acknowledge the evidence profile from which they are based. Rating the quality of evidence presented in systematic reviews is an area of constant attention. Damm and Djubegovic (2011) indicate how little consensus exists on how to rate the quality of evidence and report that 106 competing evidentiary systems were available. Among these systems, Cochrane reviews are recognised as more rigorous and better reported than other systems (Jadad et.al. 1998). It has been recognised that randomised control trials may not always be feasible and that data from observational studies may be the only source (Stroup et.al. 2000). Manchikanti (2008) indicates the importance in acknowledging the types of evidence other than randomised control trials that can be systematically reviewed. An important limitation of using the Cochrane review system for dance injury is that most of the literature is made up of observational studies and so would not qualify as admissible. With a need to create recommendations for dance using the available evidence from the methodologies employed other systems need to be considered. The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system for rating quality of evidence and grading strength of recommendations in systematic reviews is used by more than 55 organisations in 23 countries including the World Health Organisation (WHO), National Institute of Clinical Excellence (NICE) and the Cochrane Collaboration (Damm and Djubegovic 2011), as well as medical journal publishers like the British Medical Journal (Guyatt et.al 2011). GRADE is appropriate to use in high and low level evidence and has the ability to rate observational studies as well as randomised control trials (Guyatt et. al. 2011; Manchikanti 2008). The GRADE system begins with the development of an explicit framing question and includes specification to all important and critical patient outcomes. This is then followed by the collection and summarising of evidence, which is then rated using explicit criteria for rating the evidence and providing an evidence profile through examination of the study design, risk of bias, imprecision, inconsistency, indirectness and publication bias across all important and critical patient outcomes. The recommendations then arise out of the balance between benefits and harms and the strength of recommendations (Guyatt et. al. 2011a,b,c,d,e,f,g,h; Guyatt et.al. 2013a,b,c; Balshem et. al. 2011; Brunetti et. al. 2013; Andrew et. al. 2013). Manchikanti (2008) indicates that the GRADE system "enables more consistent judgements, and communication of such judgements can support better informed choices in healthcare".

Therefore the objective of this chapter was to undertake an up-to-date systematic review of the literature pertaining to musculoskeletal injury and pain in dancers using the GRADE system, AMSTAR Tool and PRISM statement, in order to establish the level of evidence and strength of recommendations for reducing the overall incidence of injuries in dancers.

2.2 Method

This systematic review was undertaken using three guidelines: the GRADE system (Guyatt et. al. 2011a,b,c,d,e,f,g,h; Guyatt et.al. 2013a,b,c; Balshem et. al. 2011; Brunetti et. al. 2013; Andrew et. al. 2013a,b; Brozek et. al. 2009a; Brozek et. al.2009b; Brozek et. al. 2011), the AMSTAR tool (Shea 2007) and the PRISMA statement (Moher et. al. 2009).

2.2.1 Literature review

A framing question was set prior to commencing the literature review: To evaluate the available literature from 1966 to 2013 to determine the level of evidence around musculoskeletal injury rates and pain in dancers and the potential impact that comprehensive medical management may have on overall injury rate and pain.

A systematic search of the scientific literature was then undertaken using the following electronic databases: the Cochrane Library; Medline (1966-April 2013); the Allied and Complementary Medicine Database (AMED); Cumulative Index to Nursing and Allied Health (CINAHL 1966-2013); SPORTDiscus (1985-April 2013); and the International Bibliography of Theatre and Dance (1984- April 2013). The following MeSH terms were combined with dance and ballet: injury; injuries; epidemiology; rehabilitation; treatments; prognosis; diagnosis; pain; prevention; screening; musculoskeletal; incidence; prevalence. In addition specialised journals (including Medical Problems of Performing Artists and Journal of Dance Medicine and Science) as well as reference lists of relevant studies were also examined. All titles and abstracts were retrieved. The criteria for retrieval were if the information in the title or abstract fulfilled the following:

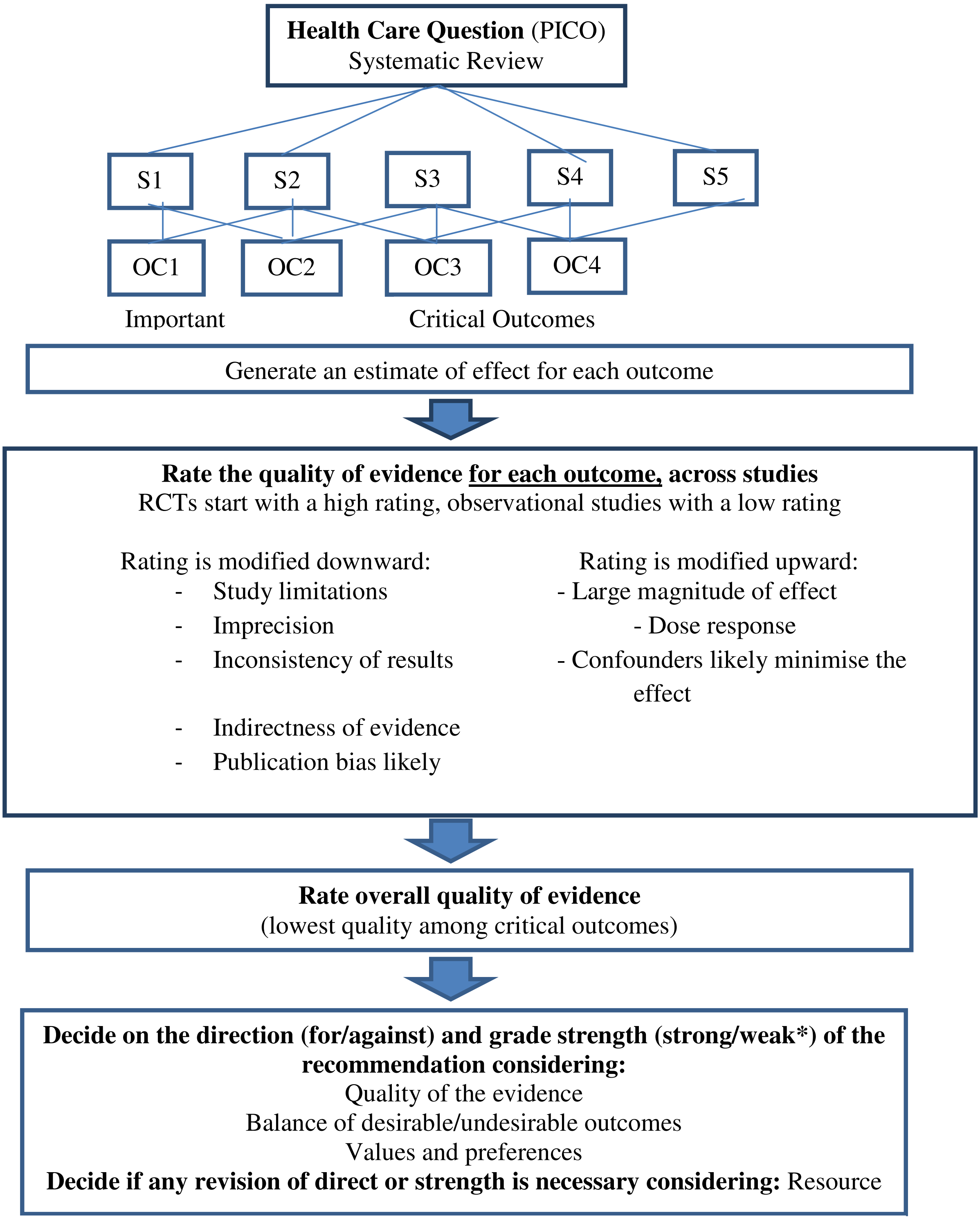
- The study was based on ballet or any forms of artistic dance
  and
- had as its focus musculoskeletal injuries or pain,
  or
- screening for injury prevention
  or
- interventions to reduce musculoskeletal injury or pain.

If there was insufficient information in the title or abstract to determine its inclusion a full text manuscript was retrieved and a review was undertaken with the full inclusion and exclusion criteria applied.

Studies were excluded if they pertained to recreational, social or aerobic dance forms. Studies were also excluded if they contained: single case or single pathology studies; psychological aspects as the primary focus; clinical evaluations of treatments for a named/specific pathology. Non-English language studies, chapters in books, abstracts and poster presentations were also excluded. Applying the inclusion and exclusion criteria, two independent authors appraised the relevance of each identified study in order to agree the final list of included studies.

2.2.2 Critical Review of included literature

Each included study was summarised in a table using a number of categories: author and date; participants including level and style of dance; methodology; response rate if applicable; sample size and study duration; injury definition applied; outcomes relating to injury as incidence, prevalence or number of injuries; outcomes relating to severity as days lost; the application of an intervention if applicable; and any additional comments.



*Also labelled "conditional" or "discretionary"

Figure 2.1: Schematic view of GRADE's process for developing recommendations

In order to develop recommendations utilising GRADE a systematic process is undertaken (Figure 2.1) (Guyatt et. al. 2011). The basis of the data collected in Table 2.2 allowed two key patient important outcomes to be determined, namely INJURY RATE as an important outcome and INJURY REDUCTION as a critical outcome. These outcomes were then used to determine the quality of the evidence presented (Table 2.1) and the strength of subsequent recommendations (Balshem et. al. 2011).

Table 2.1: GRADE Definitions of the four levels of evidence

Quality level	Current definition
High	We are very confident that the true effect lies close to that of the estimate of the effect
Moderate	We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low	Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very Low	We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

The rating of evidence is achieved through the Evidence Profiles for the respective "patient important outcomes" within which an evaluation of the evidence in relation to limitations, inconsistency, indirectness, imprecision and publication bias is undertaken across the studies. Optimal Information Size (OIS) was calculated using two sample size calculators: the OpenEpi sample size calculator for a descriptive study (http://www.openepi.com/OE2.3/SampleSize/SSPropor.htm); and the Sampsize: Sample size and Power V0.6 (2003) for sample size for a prevalence survey, with finite population correction (http://sampsize.sourceforge.net/iface/). The Evidence Profile for injury incidence also includes a calculation of the mean injury incidence per 1000hrs with 95% Confidence Intervals and number of injuries per dancer per year across the relevant studies with 95% Confidence Intervals. The Evidence Profile for injury reduction includes a calculation for the control/ pre-intervention mean incidence/1000hrs, range and 95% Confidence Intervals, or number of injuries (and range) and a test/post-intervention mean injury incidence/1000hrs or number (and range).

The GRADE system distinguishes between the roles of those providing systematic reviews with those charged with guideline recommendations (Guyatt et. al. 2011). Within the GRADE system the end-point of the systematic review is the presenting of the evidence reports and a summary of the evidence. This information is then taken on through the guideline process as a key milestone on the path to a recommendation. The development of the guideline then involves the balance between desirable and undesirable outcomes and the application of patient focussed values and preferences (as well as other stakeholders) to determine the direction of the recommendation. These issues are taken alongside the quality of the evidence to then determine the strength of the recommendation. For the purpose of recommendations, the quality ratings reflect the confidence that estimates can support a particular recommendation (Balshem et.al. 2011). Balshem et. al. (2011) does indicates that although a higher quality of evidence is more likely to be linked to a stronger recommendation in a guideline than a lower quality of evidence, a particular level of evidence does not imply the same strength recommendation and that sometimes a low or very low quality of evidence can lead to a strong recommendation. Recommendations are reported as a STRONG or WEAK recommendation (but could be phrased as conditional, discretionary or qualified) and reflect the confidence that the desirable effects outweigh the undesirable effects (of the intervention) (Andrews et.al. 2013). This is taken in respect to a comparator. The GRADE system requires that recommendations should always specify both the population group and the comparator. It is also stipulated that strong recommendations do not necessarily constitute a priority recommendation.

2.3 Results

A total of 3055 titles and abstracts of studies were reviewed. Applying the retrieval criteria 239 studies were retrieved for full, in-depth review. Using the inclusion and exclusion criteria, 47 were then accepted and preceded to evaluation as part of this systematic review (Figure 2.2).

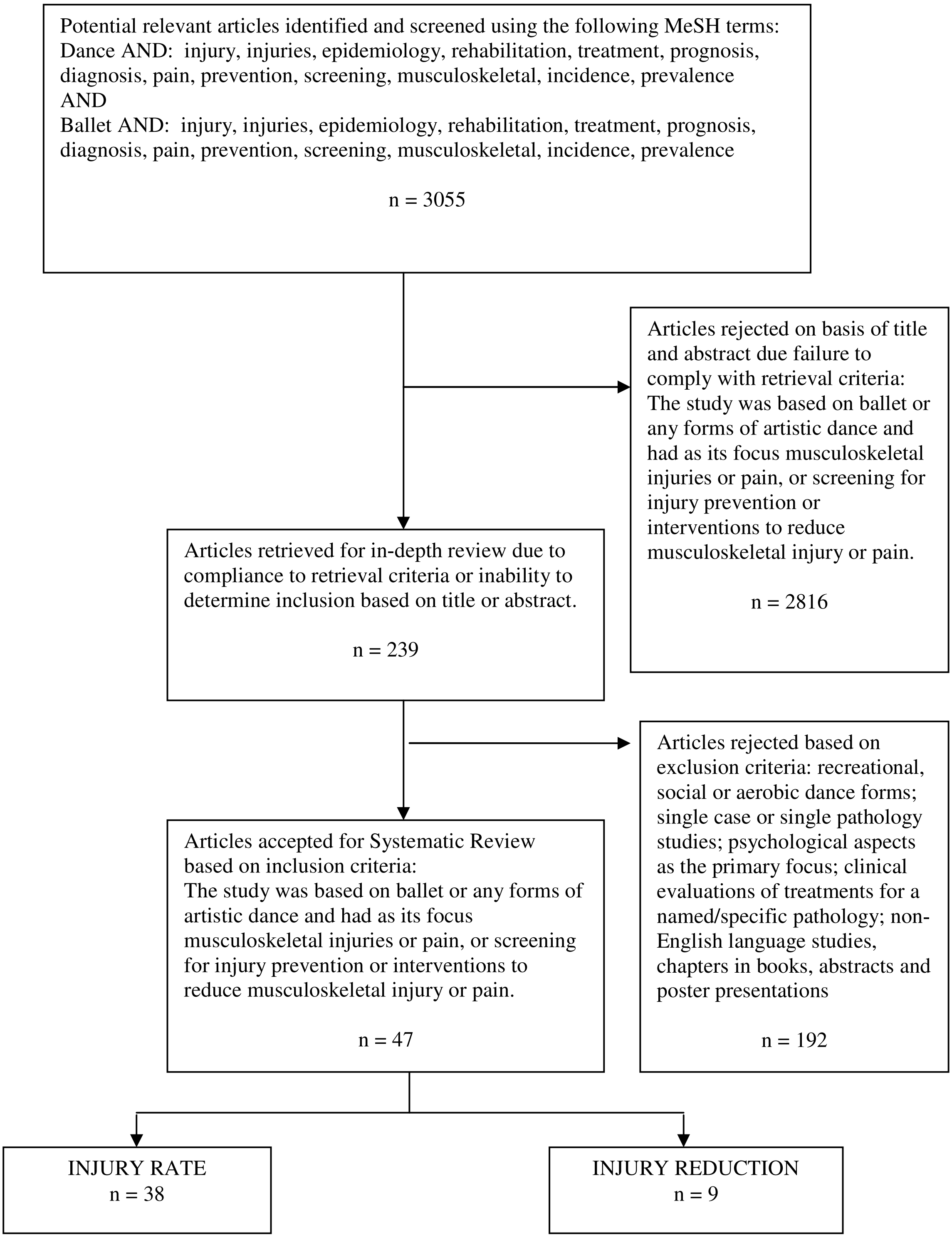


Figure 2.2: Schematic of systematic retrieval of studies

The majority of the studies related to ballet and modern or contemporary dance but other styles included break-dance, hip hop, theatrical dance, Mexican, Spanish, tap, Morris, flamenco, Irish, highland, jazz or a mix of styles. Participants were from professional or competitive dance backgrounds as well as student or vocational dance environments. Of studies accepted, 36 were conducted using a retrospective methodology including review of medical records or surveys while only 9 were prospective methodologies with a further two studies combining both retrospective and prospective components. Injury definitions varied between time loss to medical records or seeking medical attention to financial outlay. Some studies did not explicitly indicate the injury definition used. Details of injury were reported in a number of ways, including incidence, prevalence, injury per dancer or total numbers of injuries but very few papers reported severity of injuries (Table 2.2).

Table 2.2: Articles accepted for systematic review

Author/date	Participants/level, Style	Response rate	Method	Sample size/duration	Injury definition	Outcomes: incidence/prevalence	Outcomes: Severity (time loss in days)	Intervention	Other/comments
Allen et.al. (2012)	Professional Ballet	100%	Prospective cohort	52/one year	Time loss (after 24hrs)	Overall incidence 4.4/1000hrs	mean severity 7 days (female 4, male 9)	Screening/ individual conditioning programmes	
Allen et.al. (2013)	Professional Ballet	100%	Prospective cohort	52/Year 1 58/Year 2 53/Year 3	Time loss (after 24hrs)	Overall incidence Year 1:4.4/1000hrs Year 2:2.1/1000hrs Year 2:2.0/1000hrs	mean severity , year 1: 7 days, year 2: 9 days, year 3: 11 days	Injury audit, screening, individual conditioning programmes	
Twitchett et.al. (2008)	Full time students, Ballet	Unknown (volunteers from two vocational dance schools)	Retrospective survey	42/one year	Not explicitly defined but time loss is recorded	Frequency (n/yr) acute: Female 0.29+-0.5 Male 0.54+-0.6 Overall 0.35+-0.5 Overuse: Female 0.45+-0.6 Male 0.18+- 0.4 Overall 0.38+-0.5	Time off acute: Female 4.87+-16.5 Males 11.72+-19.3 Overall 6.66+-17.3 Overuse: Female 6.90+-17.9 Male 2.54+-6.4 Overall 5.76+-15.8 Total time off: Females 51.6 +- 91.0 days Males 68.6 +- 105.8days Overall 56.0+- 94.1 days		Study focussed on body composition and ballet injuries
Echegoyen et.al. (2010)	Students, modern, Mexican folkloric, Spanish dance	100%	Prospective cohort	444/3 Years 165/Year 1 146/Year 2 133/Year 3	Time loss (injury arising from dance activities resulting at least one absence from a dance class or rehearsal)	4/1000 training ours (modern) 1.8/1000hrs (Mexican Folkloric) 1.5/1000hrs (Spanish)	-	-	
Ruemper et.al. (2012)	Contemporary students	Unknown	Retrospective injury survey	85 respondents unspecified duration	Physical complaint, medical injury and time loss	Total 124 injuries (68 physical complaint, 40 medical, 17 time loss)	Not specified	-	Focus on hypermobility

Author/date	Participants/level, Style	Response rate	Method	Sample size/duration	Injury definition	Outcomes: incidence/prevalence	Outcomes: Severity (time loss in days)	Intervention	Other/comments
Lundon et.al (1999)	Vocational school, ballet	Unknown	Retrospective medical records	1023 medical charts over 25 years	Not specified	Not specified- 1023 medical charts	-	-	Focus on stress fractures
Luke et.al. (2002)	Pre-professional/student , modern and ballet mixed	39/55	Prospective cohort	39 students 9 months	any damaged part that interfered with training or any complaint about which the dancers have questions	112 self-reported and 71 reported injuries. 4.7SRIs/1000hrs, 2.9RI/1000hrs	not explicit		
McGuinness & Doody (2006)	student , Irish dance	not specified	questionnaire	159 (injury history of their three most recent injuries)	any injury that lead to absence from training and competition for two weeks or more	191 injuries	26% 14-21 days, 63% 21+days, 11% on-going		
Klemp & Learmonth (1984)	professional ballet	not specified	retrospective medical records/ workman's compensation board	47/10years	Not specified, workman's compensation	258 total injuries over 10 years	Classified as mild, moderate and severe but not average over injuries		focus on hypermobility
Ojofeitimi & Bronner (2011)	professional modern		retrospective cohort	30 + 12 annually /8years (87 different dancers)	a physical insult that required financial outlay (workers compensation or self-insurance) or caused a dancer to cease dancing beyond the day of injury	217 total injuries, 2.9injuries/dancer. Mean 0.41/1000hrs, pre-intervention: 0.52/1000hrs, early intervention 0.48/1000hrs, late intervention 0.25/1000hrs	86% minor (7 or less days away from dance), moderate 11%, severe 3% (greater than 28days)	in house medical provision	
Negus et.al. (2005)	pre-professional ballet students	not specified	Retrospective survey (injury data)	29/ 2 years (injury data)	any pain, discomfort, or other musculoskeletal problem, which required modification of , or time away from dance training, examinations or performance	82 injuries in total to 100% of sample			only lower limb injuries recorded

Author/date	Participants/level, Style	Response rate	Method	Sample size/duration	Injury definition	Outcomes: incidence/prevalence	Outcomes: Severity (time loss in days)	Intervention	Other/comments
Leanderson et.al. (2011)	student ballet		retrospective survey	476/August 1988 to June 1995	medical attention	0.8/1000hrs	not indicated		injury data based on old medical records
Cho et.al. (2009)	break-dancers, professional, amateur	not specified	retrospective questionnaire	42/duration related to the amount of time respondents been break dancing	hospital visit or injury that had been diagnosed since starting break dancing	193 injuries in total, 5.78/dancer	not indicated		
Miletic et.al. (2009)	international popular dance style (Dance Sport)	96/347	SEFIP questionnaire	96	self-reported pain status	most subjects reported pain on level 1 (some pain), 18 level 2 (much pain but can handle it), 2 level 3 (much pain, must avoid some movements)	not indicated		only females recorded
Miletic et.al. (2011)	international popular dance style (Dance Sport)	86	SEFIP questionnaire	86	self-reported pain status	most subjects reported pain on level 1 (some pain), 27 level 2 (much pain but can handle it), 3 level 3 (much pain, must avoid some movements)			
Mayers et.al. (2003)	tap, amateur and professional		retrospective survey	104 (90 female, 14 male)	musculoskeletal episodes resulting in missed dance time	total 94 injuries (female 0.34/1000dance exposures, male 0.21/1000dance exposures)	Not specified		
Gamboa et.al.(2008)	pre-professional ballet students		retrospective review of medical records	204/5 years	dancer sough at least one session from a physical therapist	overall 0.77/1000hrs, year 1: 0.56/1000hrs, year 2: 0.84/1000hrs, year 3: 0.70/1000hrs, year 4: 0.75/1000hrs, year 5: 0.93/1000hrs		Screening	

Author/date	Participants/level, Style	Response rate	Method	Sample size/duration	Injury definition	Outcomes: incidence/prevalence	Outcomes: Severity (time loss in days)	Intervention	Other/comments
Rovere et.al. (1983)	theatrical dance students		medical record review	185/September 1981-May 1982	not specified- required medical attention	352 in total, 309 dance related	not indicated		
Campoy et.al. (2011)	dance festival participants (ballet, jazz/contemporary, street dance, tap/folk		retrospective cross sectional study	500/1 year	any pain or musculoskeletal condition resulting from training and competition sufficient to alter the dancers normal routine in terms of form, duration, intensity or frequency	627 injuries to 377 dancers.			
Bronner et.al.(2003)	professional modern dance		retrospective/ prospective cohort	42dancers/5 years	any musculoskeletal complaint resulting in financial outlay	year 1: 0.51/1000hrs; year 2:0.48/1000hrs; year3: 0.57/1000hrs; year 4:0.29/1000hrs; year 5:0.18/1000hrs	year 1 total days lost (due to workers compensation injuries) 230 days; year 2:135 days; year 3: 70 days; year 4:58 days; year 5:87 days	comprehensive medical management from year 3 incl in house medical team, screening, conditioning programmes	Authors indicate some data used in calculating severity was missing or unknown
kish et.al. (2003)	dance students (ballet, jazz, tap)	137/3700	retrospective survey	137. Duration not indicated	not indicated	total of 226 injuries reported	not indicated	n/a	
Kauther et.al. (2009)	break-dance		retrospective survey	40 professionals, 104 amateurs	50 named injuries in 9 anatomical regions	1665 acute injuries	average time loss of 5.8 days per injury	n/a	
Ojofeitimi et.al. (2012)	312 competitive hip hop	not specified	Retrospective survey	232/12months	"a physical complaint sustained as a direct result of dancing"	232 dancers reporting 738 injuries	-	-	-
Garrick (1999)	Pre-professional/student, ballet	not specified	Prospective cohort	59/20months	injury defined based on symptoms	194 injuries to 38 students	not collected	n/a	

Author/date	Participants/level, Style	Response rate	Method	Sample size/duration	Injury definition	Outcomes: incidence/prevalence	Outcomes: Severity (time loss in days)	Intervention	Other/comments
Byring & Bo (2002)	professional ballet	41/51	Prospective cohort	41 dancers/19 weeks	an injury that occurs as a result of participating in dancing, leads to a reduction in the level of training, and requires a need for advice or treatment	64 total injuries, 3.2/dancer	majority reported as mild (1-7days) to moderate (8-21days)		
Weisler et.al (1996)	ballet and modern dance students	148/170	Prospective cohort	148/one academic year	any acute or chronic problem that warranted attention by the Health Services Department	177 injuries in total	not recorded		only lower limb injuries reported
Weigert & Erickson	modern dance, university level	22/30	Prospective cohort	two semesters	access to clinic/medical records	30% injured in first semester and 36.4% in second semester	mean days missed 7.27 first semester and 8.73 second semester	Screening	
Tuffery (1989)	Morris	29%	Retrospective survey	149/ 1 calendar year	acute: caused by a specific event, Chronic injury as aggravated by Morris dancing and which prevented or caused considerable pain when dancing	129 acute injuries, 47 chronic injuries, aprox. 1/1000hrs dancing	not indicated		
Steinberg et.al.(2011)	1336 non-professional, mixed styles incl. ballet, modern, jazz		Prospective cohort	1336	medical attention	1051 total injuries, 0.84/1000hrs			only female dancers recorded
Shah et.al. (2012)	professional modern	185/641	Retrospective survey	184	a medical problem that occurred as a result of participation in dance class, rehearsal or performance, such that the dancer missed or had to decrease his or her level of participation in class, rehearsal or performance	0.59/1000hrs	no severity for overall incidence reported		

Author/date	Participants/level, Style	Response rate	Method	Sample size/duration	Injury definition	Outcomes: incidence/prevalence	Outcomes: Severity (time loss in days)	Intervention	Other/comments
Baker et.al. (2010)	Contemporary students		Retrospective survey	57/ Sept 2006-June 2007	physical damage to the body or body part which prevented completion of one or more entire curriculum class	75 injuries on total	not reported		
Scialom et.al. (2006)	professional contemporary	30/40	retrospective survey	30	"their most important injury"	not indicated specifically	not reported		only recorded "their most important injury"
Rietveld (2000)	dancers and dance teachers>45years, all styles		Retrospective medical records	66/April 1993-March 1996	medical attention	total 92 injuries, 1.4 injuries/dancer	not reported		dancers >45 years old
Pearson & Whitaker (2012)	ballet students		Retrospective survey	67	occurred or was first noticed during ballet practice	36 dancers (55%) reported a relevant injury			only below knee injuries were reported. Injuries occurring before using Pointe shoes were disregarded
Solomon et.al. (1995)	professional ballet		Retrospective	70/1 year	medical attention	137 total (male: 58, female: 79)	101 injuries classified as grade 1: less than a week away; 34 injuries grade 2: one week or more.	self-insurance against medical costs	discrepancy in severity figures in table appears to be in grade 2 17-20year old injuries
Solomon et.al. (1996)	professional ballet		retrospective	70/year 1; 60/year 2;60/year 3	medical attention	year 1:137; year 2:128; year 3:88	not indicated	injury audit, in-house medical provision	
Solomon et.al. (1999)	professional ballet		retrospective	70/year 1; 60/year 2;60/year 3; 60/year 4; 59/year 5	medical attention	year 1: 137; year 2:128; year 3:96; year 4:98; year 5: 101		injury audit, in-house medical provision	discrepancy between year 3 data compared to previously published reports
Nilsson et.al. (2001)	professional ballet		retrospective/ prospective cohort	98 dancers/5 years	medical attention	0.6/1000hrs	median full withdrawal 2.3 weeks		
Pedersen & Wilmerding (1998)	student and professional flamenco dancers	80/150	retrospective survey	80 dancers-injury data collected over lifetime of dance	not explicit but injuries sustained during participation in flamenco	50 injuries in total (20 to students, 30 to professionals)			only looked at overuse injuries sustained during Flamenco dancing

Author/date	Participants/level, Style	Response rate	Method	Sample size/duration	Injury definition	Outcomes: incidence/prevalence	Outcomes: Severity (time loss in days)	Intervention	Other/comments
Ramel & Moritz (1994)	professional ballet	128/147	retrospective survey	128/injury data collected in relation to last 12 months	From the Nordic Questionnaire, "any trouble (ache, pain, discomfort)"	121 dancers reported experiencing some trouble, 472 problems reported.	168 problems prevented dancers doing their daily work.		
Ramel et.al. (1999)	professional ballet	72%	retrospective survey	51 over 12 months	From the Nordic Questionnaire, "any trouble (ache, pain, discomfort)"	443 problems reported in 1995 (compared to 403 to the same 51 dancers in 1989)	1995:132 injuries causing incapacity in last 12 months; 1989: 161 injuries causing incapacity in last 12 months		some missing data reported
Evans et.al. (1996)	professional Broadway dancers and actors	40.80%	retrospective survey	318 over the duration of the Broadway production (166 dancers)	self-reported	for 166 dancers: 218 injuries in total			
Quirk (1983)	student and professional ballet		retrospective medical records	664/15 years	medical attention	2113 injuries			
Chmelar et.al. (1987)	professional and student ballet and modern	not specified	retrospective survey	39 dancers/	taken from the questionnaire: "have you sustained any major injuries that have kept you away from dancing for more than 2 or 3 weeks; do you have any recurrent physical nuisances that interfere with but do not stop your dancing	46 injuries			only female dancers surveyed
Bowling (1989)	professional modern and ballet	75%	retrospective survey	141 dancers/ 6 months recall	self-reported injury	118 dancers had at least one injury			

Author/date	Participants/level, Style	Response rate	Method	Sample size/duration	Injury definition	Outcomes: incidence/prevalence	Outcomes: Severity (time loss in days)	Intervention	Other/comments
Bronner & Brownstein (1997)	professional Broadway dancers		medical record review	30 dancers/ 7 weeks	time loss from performance	40% injury rate; 1.0injuries/dancer	82 missed and 35 partial performances		
Nunes et.al. (2002)	recreational ballet		questionnaire	31 dancers (12 non-Pointe, 19 Pointe)	no explicit- reports painful sites	mean number of painful sites reported. Non-Pointe: 1.3; Pointe 2.9			females who had either never danced in Pointe shoes, or those who had danced for at least 18 months were included

Within the Evidence Profile for INJURY (Table 2.3) a mean incidence of 1.33/1000hrs for the 12 observational studies that reported incidences of injury was calculated. An average of 1.93 injuries per dancer per year was calculated from 29 studies that had sufficient data.

Table 2.3: Evidence Profile- INURY (Injury Incidence and No. of Injuries)

No of studies (design)	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Average incidence/1000hrs (Range of incidence/1000hrs) (95%CIs)	Actual no. of injuries/no of participants/year (range) (95%CIs)	Quality
Overall injury incidence 29 (observational)	serious limitations	serious inconsistency	no serious indirectness detected	no imprecision	undetected	1.33injuries/1000hrs (0.18-4.7injuries/1000hrs) (0.20-4.35)*	1.93 injuries/dancer/year (0.05-6.83)(0.29-4.5)	very low
						*based on 12 studies		

These studies demonstrated serious limitations (including the lack of the inclusion of control populations and flawed exposure measurements), inconsistencies (including the inconsistency of results within the studies and heterogeneity) while there was no imprecision due to the sample size (n=2788 and 5318) being greater than the sample size calculated (n>385) (TABLE 2.4 and 2.5), indirectness or publication bias was noted. This resulted in a downgrading of the LOW evidence assigned to observational studies within the GRADE system to VERY LOW.

Table 2.4: Sample size calculation 1 (Sampsize)

Assumptions	
Precision	5.00%
Prevalence	50.00%
Population size	infinite
95% Confidential Interval specified limits (45%-55%)These limits equal prevalence plus or minus precision	
Estimated sample size	n=385
95% Binomial Exact Confidence Interval with n=385 and n*prevalence=193 observed events: (45.0212%--55.2365%)	

Table 2.5: Sample size calculation 2 (OpenEpi)

Assumptions	
Population size(for finite population correction factor or fpc)(*N*):	1000000
Hypothesized % frequency of outcome factor in the population (*p*):	50%+/-5
Confidence limits as % of 100(absolute +/- %)(*d*):	5%
Design effect (for cluster surveys-*DEFF*):	1
Sample size (n)for confidence levels	
95%	385
Equation	
Sample size ***n* = [DEFF*Np(1-p)]/ [(d²/Z²₁₋α/₂*(N-1)+p*(1-p)]**	

The Evidence Profile for INJURY REDUCTION noted a reduction from a mean incidence of 2.46/1000hrs to 0.84/1000hrs. These 2 observational studies demonstrate serious limitations (due to the lack of the inclusion of control populations), inconsistency (due to the range of results reported and heterogeneity) and imprecision (due to the sample size (n=363) being less than the sample size calculated (n>385)) (TABLE 2.4 and 2.5). Publication bias is also likely with both studies demonstrating significant reductions in injury incidence and so be favoured for publication over studies that failed to demonstrate statistically significant findings. With these factors in mind the Evidence Profile rating is downgraded from LOW for observational studies to VERY LOW (Table 2.6).

Table 2.6: Evidence Profile- INURY REDUCTION (Injury Incidence)

No of studies (design)	limitations	inconsistency	indirectness	Imprecision	Publication bias	total number of injuries (Range of incidence/1000hrs) (95%CIs)	Test/ post-intervention: Average incidence/1000hrs (Range of incidence/1000hrs)	Quality
Comprehensive medical provision 2 (observational)	serious limitations	serious inconsistency	no serious indirectness detected	serious imprecision	likely	2.46/1000hrs (0.52-4.4/1000hrs)	0.84/1000hrs (0.18-2.1/1000hrs)*	very low
							*representing/over 7 years	

A further 3 observational studies demonstrated a reduction in injury numbers from 137 to 106. These studies also demonstrated serious limitations (due to the lack of the inclusion of control populations) and imprecision (due to the less than optimal information sample size) and so the Evidence Profile was rated down from LOW to VERY LOW (Table 2.7).

Table 2.7: Evidence Profile - INJURY REDUCTION (injury numbers)

No of studies (design)	limitations	inconsistency	indirectness	Imprecision	Publication bias	Control/ pre-intervention: Average injury numbers (Range of total injury numbers)	Test/ post-intervention: Average injury numbers (Range of injury numbers)	Quality
Comprehensive medical provision 3 (observational)	serious limitations	no serious inconsistency	no serious indirectness detected	serious imprecision	likely	137 (137)	106 (96-128)*	very low
							* representing/over 4 years	

Using the GRADE framework for moving from evidence to recommendation, a strong recommendation for the use of comprehensive medical management for the reduction of injury rate in dancers is advocated in the absence of stronger evidence (Table 2.8).

Table 2.8: GRADE Recommendation for Injury Reduction

Question/recommendation: Should comprehensive (in-house) medical management vs. off-site medical referrals be used to reduce injury rate in professional dancers				
Population: Professional dancers (ballet and modern)				
Intervention: Comprehensive In-house Medical Management (including Injury audit/Screening/Intervention programmes) vs. offsite medical referrals				
Setting: Professional dance companies				
Decision domain	Judgement		Reason for judgement	Sub domains influencing judgement
	Yes	No		
Balance of desirable and undesirable outcomes: Given the best estimate of typical values and preferences, are you confident that the benefits outweigh the harms and burdens or vice versa?	x		The desirable outcomes are a reduction of injury rate. There is no evidence to suggest the use of in house comprehensive medical management would be detrimental to the patient group	The size and specialities within the comprehensive medical management has not been established. Similarly if differences are needed for various sub-group populations, i.e. ballet or modern?
Confidence in estimates of effect (quality of evidence): Is there high or moderate quality evidence		x	The evidence profile for this outcome is very low for the desired outcome. There is no evidence to any detrimental/harm outcome through utilising this intervention	Key reasons for rating down of evidence is through the use of observational studies with certain limitations in the GRADE rating factors
Values and preferences: Are you confident about the typical values and preferences and are they similar across the target population?	x		We can be confident that professional dancers place a high value on a reduction in injury rate as their livelihood is dependent on their ability to dance	The increasing number of higher quality studies into injury rate reflects the position of the dance environment
Resource implications: Are the resources worth the expected net benefit from following the recommendation?	x		There is a resource need to provide in-house medical provision. This has been demonstrated to reduce the overall medical costs and outweigh the costs of its implementation.	Although not explicitly examined as part of the review, the use of in-house medical teams are becoming more common place- the implementation of injury audits, screening and programme interventions could be seen as sunk costs. Cost per resource unit needs to be established.
Overall strength of recommendation	Strong		The author recommends that the injury rate of dancers in professional companies will be reduced through the use of comprehensive medical management.	
Evidence to recommendation synthesis	The high value placed on injury reduction through comprehensive medical management versus harm outweighed the lower evidence profile in the absence of stronger evidence			

2.4 Discussion

The aim of this review was to provide an up-to-date systematic review of the literature pertaining to musculoskeletal injury and pain in dancers using the GRADE system in order to establish the level of evidence and strength of recommendations for reducing the overall incidence of injuries in dancers. When examining the studies retrieved through this systematic review similar findings to the two previous published systematic reviews (Hincapie et. al. 2008, Jacobs et. al. 2012) are noted in that the literature has many limitations including the variety of injury definitions used, the heterogeneous populations; identifying the at risk population and the wide range of inclusion and exclusion criteria.

It is important to recognise that a number of issues can affect the reliability and validity of outcomes within studies; these issues include: method employed; injury definition; data collection and sample size. Although, with a systematic literature review, there is an objective of creating a convergent view of the data presented to further our understanding of dance injuries, it is important to understand the individual papers objectives, and relate those to the methodologies employed and outcomes achieved. Meeuwisse and Love (1997) indicate that a number of reasons for injury surveillance exist. These include estimating the burden of morbidity (or mortality) in population groups, identifying risk factors in high risk groups, and safety decision-making and allocation of resources including healthcare. The authors also indicate its role as an outcome measure for research in injury prediction and testing the efficiency of interventional strategies in injury prevention.

Most papers have amongst their objectives explored the burden of morbidity while for others it is the key focus (Quirk, 1983; Chmelar, 1987; Bowling, 1989; Sohl and Bowling, 1990; Ramal and Moritz, 1994; Ramal et. al. 1999; Evans, 1996; Pedersen and Wilmerding, 1998, Steinberg et. al. 2011; Byhring and Bo 2002,; Kauther et. al. 2009; Ojofeitimi et.al. 2012; Kish et.al. 2003; McGuinness and Doody 2006). Nilsson et al

(2001) specifically sets out to identify risk when examining the incidence and type of musculo-skeletal injuries in relation to time lost from performance, by including in their objectives the identification of individuals at risk of frequent injuries. Similarly, Gamboa et. al. (2008) uses the findings of a screening process in relation to injury distribution and rate, to identify risk characteristics. Luke et. al. (2002) set out to test the implementation of injury audit and screening tools as part of their recommendations for future and larger study evaluating risk factors in dance. Solomon et. al. (1995, 1996, 1999) and Bronner and Brownstein (1997) and Bronner et. al. (2003) works falls under the safety decision making and allocation of resources, as they look at the financial implications of implementing a change in healthcare provision.

While it is accepted that the underlying reason for undertaking injury surveillance will influence the method employed, the method employed can affect the reliability and validity of results obtained. A major factor influencing impact of injury surveillance and as such outcomes is injury definition. As part of defining an injury incident, it is critical to include, within that definition, the severity of the injury. Without which, the value of injury incidence cannot be fully appreciated. In establishing the incidence of injuries sustained in dance we can start to use this as a measure of testing the efficacy of interventional strategies in preventing dance injuries, as indicated by Meewisse and Love (1997). The results of this systematic review demonstrated that only 29% of studies retrieved reported injury incidence. Furthermore only 27% of the studies specifically take account of the severity of injuries reported. Within this systematic review less than 20% of the studies elected on a full prospective methodology (Allen et. Al. 2012; Allen et. al. 2013; Luke et.al. 2002, Echegoyen et.al. 2010; Garrick 1999; Byring & Bo 2002; Weisler et.al 1996; Weigert & Erickson 2007; Steinberg et.al. 2011). A challenge to utilizing a retrospective survey type design, is that it is often down to the test subject's interpretation of injury, and this is evident amongst the majority of dance injury surveillance papers (Chmelar, 1987; Bowling, 1989; Evans et. al., 1996; Pedersen and Wilmerding, 1998).

As previously discussed, the methodology employed, and the subsequent choice of injury definition, is linked to the outcomes and objective set for the particular research. Part of the objectives of Chmelar (1987) and Bowling (1989) was to ascertained dancers own perception of their injuries, training and well-being therefore it could be considered an appropriate choice for that particular study. Some retrospective survey studies have a time-loss injury definition (Bronner et. al. 2003). When using time loss injury definition, there is an opportunity to under-report less serious injuries that could either affect performance capacity or could form part of a more serious injury sequence if the definition is limited to those injuries resulting in full withdrawal from dance related activities. Ramal and colleagues (1994, 1999) have included injuries that affect activity rather than solely by time-loss alone, which allows less serious injuries still to be documented. Luke et. al. (2002) designed a study to prospectively evaluate injuries that affected dancer performance using both dancer self-reporting and medical attention guided by a scale of limited function, provided some interesting insight as to the reporting of injuries, where a proportion of injuries confirmed through medical attention were not reported in the self-reporting surveys, despite them being bi-weekly to limit recall bias. A similar link between methodology and injury definition and objectives is seen with Bronner and colleagues (1997, 2003) and Solomon and colleagues (1995, 1996, 1999), who both set out to determine the financial impact of a change in healthcare provision, and as such have used financial outlay as a criteria in defining injury.

The use of medical records or attendance with a healthcare professional as an injury definition (Quirk, 1983; Nilsson et. al., 2001; Reitveld 2000; Gamboa, 2008; Steinberg et.al. 2011) falls under a case series design. This type of design has been linked to provide an advantage in environments where injury occurrence is low but severity is high, as in catastrophic head and neck injuries (Meewisse and Love, 1997). From the evidence available, it would appear that there is not a high incidence of these types of severe injuries in dance. Challenges to this definition include whether the injury data collected truly represents the state of injuries in dance, particularly less severe injuries, as well on reporting injuries in relation to exposure, where exposure periods may not be quantified? With failure to realise the full population that is at risk, as well as failure to document exposure data, risk and causal associations cannot be assessed.

The nature of data collection can affect the validity of results obtained. The use of injury reporting systems can be seen within medical and sports literature (Hodgson-Phillips, 2000). Only Ramal and colleagues (1994, 1999) use a standardised injury reporting system, namely the Nordic Musculoskeletal Questionnaire, with additional questions added to explore the specificity of this particular cohort. The advocacy of a standardised injury reporting system in dance is recognized (Liederbach and Richardson, 2007; Bronner et. al., 2006). A component of data collection also includes the use of standardized injury diagnosis codes. A number of injury diagnosis code systems exist within the sports medicine literature (Meeuwisse and Love 1997, van Mechelen et. al. 1992). Within the systematic review performed for this study, only two papers used an injury diagnosis coding system (Allen et. al. 2012, Allen et. al. 2013).

Another key aspect in understanding risk factors with injury surveillance outcomes is determined by the power of a research paper. The power of a paper is described as "its ability to demonstrate that there is an association between a risk factor and an injury, given that the association exists (Elwood 1998). Sample size plays an important role in determining the power of a research study's outcomes. Bahr and Holme (2007) indicate sample size calculations should be performed specific to the statistical test which will be used to evaluate the main effect. Schmoor, Sauerbrei, and Schumacher (2000) indicate that a strong relationship in combination with a fairly prevalent injury type would be needed to defend a design with a sample size less than 300 subjects. It would appear from the literature reviewed so far that although some studies have documented the higher number of cases (Quirk, 1983; Leanderson et.al. 2011; Campoy et. al. 2011; and Lundon et.al. 1999), the lower prevalence rates seen diminish the power of outcomes observed.

2.4.1 GRADE Evidence Profile

One of the fundamental aspects of the GRADE system is that sequential judgements are made regarding the quality of evidence across studies for each patient important outcome (Guyatt et. al. 2011). It is determined which outcomes are critical to a decision and the overall quality of evidence across those critical outcomes and the balance between benefits and harms, and the strength of the subsequent recommendations (Manchikanti

2008). The starting point of the GRADE process is the specified approach to the framing question for the systematic review of the literature (Guyatt et. al. 2011). The system incorporates a methodology known as PICO (patient/intervention/comparator/outcome). Outcomes of interest are those that are important to the patients. It also requires that an initial rating of importance is given to the outcome. For the purpose of this systematic review the framing question was “what evidence exists around musculoskeletal injury and pain rates in dancers and the potential impact that screening and/or comprehensive medical management may have on overall injury and pain rates”. The important patient outcomes specified were the overall injury rate and the impact of interventions to reduce overall injury rate.

From the literature retrieved, 29 studies were used in an evidence profile for injury rate (injuries/dancer/year) with 12 of which allowing injury incidence to be considered. Due to the nature of these studies being observational methodologies they start with a LOW evidence profile. As per the GRADE system, this is then subsequently marked up or down based on its scientific rigor as per Figure 2.1. The purpose of this evaluation is to reflect the confidence that the estimates of the effect are correct with the final rating of overall quality occurring as a continuum of the validity, precision, consistency and applicability of the estimates (Guyatt 2011a,b,c,d,e,f, Balshem et. al. 2011).

With the studies contributing to INJURY RATE there were serious limitations or biases noted due to the failure to include control groups, flawed measurements of exposure and failure to control confounding variables including a failure of accurate measurement of all known prognostic factors and failure to match for prognostic factors. The studies in question were also noted for serious inconsistency due to the heterogeneous nature of the contributing studies. It is well appreciated that various dance styles provide differing challenges on the body (Dahlstrom et. al. 1996; Koutedakis and Jamurtas 2004) that may result in injuries as well as the potential differences in injury potential noted between professional and student participants (Allen et. al. 2012, Leanderson et. al. 2011). The GRADE system utilises the examination of 95% CI’s as the optimal primary approach to decisions regarding imprecision. Further to this, GRADE suggest that if the total number of patients included in a systematic review is less than the number of patients generated by a conventional sample size calculation for a single adequately powered trial; consider rating down for imprecision (Guyatt et. al. 2011). The sample size calculations indicated sample sizes of 385. As the pooled sample size for INJURY RATE (n=2788 and n=5319) was greater than 385 it was not rated down for imprecision. There was no evidence of publication bias noted in this outcome group. As a consequence of these issues in the absence of any upward rating through magnitude of effect, dose response or confounders likely to minimise the effect, the overall rating of LOW evidence for observational studies is downgraded to VERY LOW as a reflection of the overall confidence in the effects consistent with the GRADE definitions (Table 2.1).

Similar issues over evidence were observed when considering INJURY REDUCTION as a patient important outcome. There were serious limitations or biases noted due to the failure to include control groups, flawed measurements of exposure and failure to control confounding. The studies in question were also noted for serious inconsistency due to the heterogeneous nature of the contributing studies although these studies were limited to professional ballet and modern dancers as opposed to the range of patient groups noted in the INJURY RATE Evidence Profile. The pooled sample size (n=363) for INJURY REDUCTION was less than the required sample size of 385 so therefore was rated down for imprecision. It was also noted that publication bias was likely due to the statistical significance reported in studies resulting in their acceptance for publication as opposed to studies that may not have demonstrated significant findings. As a consequence of these issues the overall rating of LOW evidence for observational studies is downgraded to VERY LOW.

2.4.2 GRADE Recommendations

Within GRADE it is important to state the perspective that is being taken when determining guidelines. The nature of the patient important outcomes were decided from the perspective of the patient as opposed to the funders of dance related healthcare systems, thereby putting greater emphasis on reduction of injuries as opposed to costs of service/resource. Although rated as very low evidence, suggesting that the true effect may be much larger or smaller, there is sufficient call to consider means to reduce the overall injury rate in dancers. The role of comprehensive medical management as a means to address the important patient outcome of INJURY REDUCTION was demonstrated to have a VERY LOW evidence profile. To enhance the transparency when moving from evidence to recommendations using GRADE, a framework is utilised (Table 2.8). As can be seen from Table 2.8, a strong recommendation for the use of comprehensive medical management for the reduction of injury rate in dancers is advocated in the absence of stronger evidence.

The value to this system is that it allows for a strong recommendation to be made despite a lower level of evidence presented. This is through basing the recommendation on patient important outcomes and evaluating the benefit versus harm or that the desirable effects outweigh the undesirable effects in respect to the intervention. The use of comprehensive medical management for professional athletes reflects more a duty of care in modern sports medicine and so fits with a strong recommendation for its implementation in dance in the absence of higher evidence.

2.5 Limitations

Although this systematic review was conducted using a number of electronic databases, specialised journals and grey literature, the exclusion of unpublished work/thesis, poster presentations and abstracts along with chapters from books may reduce the total number of studies available from which evidence and recommendations can be drawn. Similarity the exclusion of non-English language studies is a further limitation.

2.6 Conclusion

The two previous systematic reviews (Hincapie et. al. 2008; Jacobs et. al. 2012) concluded that the quality of evidence surrounding musculoskeletal injury and pain in dancers was low. The results of this systematic review were similar when using the GRADE system. Using the GRADE system two patient important outcomes, namely injury rate and injury reduction, were examined across the studies retrieved and an overall rating of evidence for both outcomes was very low. The value of implementing GRADE is the direction and strength of recommendations may differ from the evidence profile if the proposed benefits outweigh any harm. The use of the Evidence to Recommendation Framework enhances the transparency of those recommendations. A strong recommendation for the use of comprehensive medical management for the reduction of injury rate in dancers is advocated in the absence of stronger evidence.

Chapter 3: Musculoskeletal injury and pain at a professional international touring company over 1 year

Data from this chapter has been published in Allen, N; Nevill, A; Brooks, J; Koutedakis, Y; Wyon, M (2012) Ballet Injuries: Injury incidence and severity over one year. *J Orthop Sports Phys Ther*, vol 42(9): p. 781-790 *doi:10.2519/jospt.2012.3893*

3.1 Introduction

Dance is an art form, therefore its artistic and expressive aspects are as important as the technical (Scott 1997, Van Zile 1986). Expressivity can be reliant on highly refined motor skills, detailed coordination and precision with timing (Penrod 1994, Twitchett, Angioi, Koutedakis, et. al. 2009). Although these skills are sometimes required in other sports such as gymnastics and figure skating, they are only used to enhance physical accomplishment (Angioi, Twitchett, Metsios, et. al. 2009). Alongside the expressivity and artistic nature of dance is the physicality and athletic accomplishment that has seen dancers described as a both artist and athlete (Koutedakis, Stravropoulos-Kalinoglou and Metsios 2005, Koutedakis and Jamurtas 2004, Bronner and Brownstein 1997). Like athletes, the impact of injury can be severely detrimental (Khan, Brown, Way, et. al., 1995; R. Solomon et. al. 1999; Stretanski, 2002; van Dijk, Lim, Poortman, et. al. 1995; Warren, Brooks-Gunn, Hamilton, et. al. 1986). This impact has repercussions both to the individual dancer as well as their employer. Injury can affect performance, and in the elite and professional level, where outcomes are measure by performances and not just participation, the impact may be amplified. The impact may have both health and financial ramifications, with short term as well as long term implications. Alongside the long term implications of injury, it could result in missing out on important roles in upcoming performances. The time away from training and performances can lead to a performance deficit that could in turn impact on a dancer's future position in the company.

As part of the development of professionalism in dance, there is a need to create an understanding of dance injuries and the means to which they may be addressed and prevented. Within sport some of the understanding of injury has been attributed to the progressions in sports medicine and science and the increased understanding of the needs of specific sporting populations. A fundamental model of injury prevention in sport has as its foundation the establishing of the extent of the injury problem (van Mechelen et al. 1992). Epidemiological studies play an important role in the establishing the extent of injuries in sport (Brooks et al. 2005a, Orchard and Seward 2009, Hawkins and Fuller

1999, van Mechelen et al. 1992, Parkkari et al. 2001). The role of injury surveillance and epidemiological studies has also been recognised in dance (Bronner et al. 2006, Liederbach and Richardson 2007). The results of a two previously published systematic reviews (Hincapie et. al. 2008, Jacobs et. al. 2012) of the literature pertaining to musculoskeletal injuries and pain experienced by dancers revealed the need for explicit criteria on injury definition and methods of injury reporting and comment that there are still major scientific limitations and biases in the literature reviewed. A move to improve validity of outcomes within epidemiological studies in sport, as well as allow more cross comparison between studies has resulted in the development of consensus statements on the injury data collection in football, rugby and tennis (Fuller et. al. 2006, Fuller et. al. 2007b, Pluim et. al. 2009). A key recommendation of all the consensus statements is the reporting of injury incidence through the use of prospective cohort studies with a clearly defined injury definition and an account of the exposure of subjects to improve the reliability and validity of data collected. While these were areas identified by Hincapie et. al. 2008 and Jacobs et. al. 2012, no consensus statement on injury data collection for dance has been published to date. The incidence of injury to ballet dancers has been infrequently reported and has ranged from 0.62-5.6 injuries per 1,000 dancing hours (Nilsson et. al. 2001, Luke et. al. 2002, Gamboa et. al. 2008; Leanderson et. al. 2011). The wide range of rates and incomparability of previous studies can be largely attributed to inter-study methodological variations. Three of the studies were based on pre-professional dancers (Luke et. al. 2002, Gamboa et. al. 2008; Leanderson et. al. 2011), which may be less valid to a professional ballet company due to shorter and less intensive working day (Hamilton, Aronsen, Loken, et. al. 2006; Twitchett, Angioi, Koutedakis, et. al. 2010).

Well-designed epidemiological studies can aid the understanding of the injury profile allowing appropriate interventions to mediate the risk of injury, however, the epidemiology of injuries to ballet dancers is not well understood due to varied and methodologically weakened research designs. The purpose of this single cohort observational study was to document injury incidence and severity in professional ballet dancers over a one year period. The Strengthening the Reporting of Observational

Studies in Epidemiology (STROBE) statement-checklist of items that should be addressed in reporting of observational studies (von Elm et. al. 2008) was used to strengthen the quality of the reporting in this study

3.2 Method

3.2.1 Design

A cohort of 52 professional ballet dancers (female: 27; male: 25), ranging from Artists and 1st Artists to Soloists and Principals, who made up the entire international touring company were prospectively studied over one performance year (2005-2006) (Table 3.1). This sample of convenience was studied in their home theatre as well as on tour within the United Kingdom and internationally. Optimal Information Size (OIS) was calculated using two sample size calculators: the OpenEpi sample size calculator for a descriptive study (http://www.openepi.com/OE2.3/SampleSize/SSPropor.htm); and the Sampsize: Sample size and Power V0.6 (2003) for sample size for a prevalence survey, with finite population correction (http://sampsize.sourceforge.net/iface/). All research data was collected in accordance with the University of Wolverhampton's School of Sport, Performing Arts and Leisure Ethics committee (Appendix 1 and 2).

3.2.2 Injury Reporting

A time-loss definition of injury was used whereby "any injury that prevented a dancer from taking a full part in any dance related activities that would normally be required of them for a period equal to or greater than 24 hours after the injury was sustained" (modified from Brooks et. al. 2005a) were reported by one of the 3 full-time in-house physiotherapists on a standardised injury reporting form. In order to differentiate between full withdrawal from dance related activities and partial withdrawal from dance related activities a second injury definition was included, whereby the if an injury resulted in the full withdrawal from all dance related activities (i.e. unable to participate in class, rehearsal and performance), the number of days that no dance related activity took place was recorded as "full absence from dance related activity" as a component of the overall severity in days until full participation in dance related activities took place. Injury diagnosis was recorded using the Orchard Sports Injury Classification (OSICS) version 9 (Orchard 1993). Injury meetings were held weekly with all members of the medical team to discuss and agree injury details. Dancers were assigned a rank for the year of the study based on their position within the hierarchy of the company, with each gender having Principals at the top of the hierarchy, followed by Soloists, 1st Artists and finally Artists at the lower aspect of the hierarchy. The role a dancer will undertake during a performance is largely based on their rank within the company, but dancers from lower ranks may find themselves undertaking more complex "principal" type roles. A total of 17 injuries sustained during non-dance related activities were not included in the study. Within the present study a dancer was deemed to have returned from injury when they were able to return fully to all dance related activities. A recurrent injury was defined as "an injury of the same type and at the same site as the index (first episode) injury, occurring after a dancers´ return to full participation from the index injury within one year " and an exacerbation as "a worsening in the state of a non-recovered complaint such that the dancer could not take a full part in dance related activities that would normally be required" (definitions modified from Fuller et. al. 2007a); all other injuries were classed as first episode injuries. Injuries were either classified as traumatic: "an injury that resulted from a specific identifiable event" or overuse "an injury caused by repeated micro-trauma without a single identifiable event responsible for the injury" (Fuller et. al. 2006). Based on the determinants for risk factors in sports injury (Parkkari et. al. 2001; Fuller and Drawer, 2004), the nature of injury causation was classified as intrinsic: "injuries considered to be those specific to an individual participant, including strength and joint stability"; or extrinsic: "arising from external sources, including surfaces, protective equipment, props". Exposure was recorded using detailed call sheets and performance schedules that dictated the daily activities of all dancers within the company. The standardised injury assessment form also included further details regarding the injury that was collected for future reference and was not analysed as part of this study (see Appendix 4).

3.2.3 Data Analysis

The severity of injuries was calculated as the number of days between the date of injury and the date of return and reported as mean severity with 95% confidence intervals (Weatherburn 1961) The incidence of injury and total days' absence due to injuries were calculated as the number of injuries or number of days absence per 1,000 hours of dancing with 95% confidence intervals (Weatherburn 1961). Using a Poisson distribution model to calculate confidence intervals (CI), a significant difference in variables was assumed if the 95% CI for the variables did not overlap (Brooks et. al. 2005a,b; Garraway et. al. 2000; Parekh et. al. 2012). A Pearson's correlation was applied to individually calculated injury incidences and individual injury numbers to determine if a correlation existed with age and injury. All correlations and associations were calculated using Minitab version 16 software (Minitab Inc. State College, PA).

Table 3.1: Participants Details by Rank

	Year 1			
	Female		**Male**	
Rank	(n=27)	Mean Age (SD)	(n=25)	Mean Age (SD)
Principal	4	28(4)	4	28(0)
Soloist	7	29(4)	4	27(4)
1st Artist	5	23(2)	5	24(4)
Artist	11	21(3)	12	20(2)

3.3 Results

3.3.1 Overall

The sample size of this cohort (n=52) was smaller than the sample size calculated (n>385) for improved precision of outcomes. (TABLE 3.2 and 3.3)

Table 3.2: Sample size calculation 1 (Sampsize)

Assumptions	
Precision	5.00%
Prevalence	50.00%
Population size	infinite
95% Confidential Interval specified limits (45%-55%)These limits equal prevalence plus or minus precision	
Estimated sample size	n=385
95% Binomial Exact Confidence Interval with n=385 and n*prevalence=193 observed events: (45.0212%--55.2365%)	

Table 3.3: Sample size calculation 2 (OpenEpi)

Assumptions	
Population size(for finite population correction factor or fpc)(*N*):	1000000
Hypothesized % frequency of outcome factor in the population (*p*):	50%+/-5
Confidence limits as % of 100(absolute +/- %)(*d*):	5%
Design effect (for cluster surveys-*DEFF*):	1
Sample size (n)for confidence levels	
95%	385
Equation	
Sample size $n = [DEFF*Np(1-p)]/ [(d^2/Z^2_{1-\alpha/2}*(N-1)+p*(1-p)]$	

A total of 355 injuries (female: 172; male: 183) were sustained during 79,924 hours of exposure (female: 41,499 hrs; male: 38,425 hrs). All 52 dancers in the cohort sustained at least one reportable injury (range: 1 – 17 injuries), with a mean of 6. 8 injuries per dancer (females: 6.3; males: 7.3). The incidence of injury was similar for both female and male dancers, while the mean severity was significantly higher ($p<0.05$) for male dancers (9 days) than female dancers (4 days) (Table 3.4). There were two serious male injuries (anterior tibial cortex stress fractures) resulting in a total of 493 days absence. The majority of injuries caused less than 7 days absence from full participation (female: 94%; male: 87%), Only 22 female (13%) and 36 male (20%) injuries caused complete absence from all dance related activities (class, rehearsal or performance) as a component of the overall severity (total days absence: 674; female: 52; male: 622, with an average of 12 days per dancer). The remainder of the injuries still allowed the dancers to continue with some form of modified dance activities (Table 3.5). Transient injuries were significantly higher ($p<0.05$) than all other categories in both male and female dancers.

Table 3.4: The Incidence and Severity of Injuries as a Function of Gender

	Injury incidence/ 1,000 hrs dancing (95%CI)	**Average severity (days) (95%CI)**	**Days absence/ 1,000 hrs dancing (95%CI)**
Female (n=27)	4.14 (3.57-4.81)	4 (3.48-4.69)	17 (14.4-19.4)
Male (n=25)	4.76 (4.12-5.51)	9 (8.12-10.85)	45 (38.68-51.68)
Total	**4.44 (4.00-4.93)**	**7 (6.13-7.54)**	**30 (27.21-33.50)**

Table 3.5: Injury Incidence for Female and Male Dancers that included Full Withdrawal from Dancing Activities, Number of Injuries and Incidence per 1000 hours of Dancing

	Female dancers		**Male dancers**	
	Number of injuries (% of all injuries)	**Injury incidence/ 1,000 hrs dancing (95%CI)**	**Number of injuries (% of all injuries)**	**Injury incidence/ 1,000 hrs dancing (95%CI)**
Restricted dance activity	150 (87)	3.6 (3.1-4.2)	147 (80)	3.8 (3.3-4.5)
Complete withdrawal from dance related activity*	22 (13)	0.53 (0.35-0.81)	36 (20)	0.94 (0.68-1.30)
ALL INJURIES	**172 (100)**	**4.1 (3.6-4.8)**	**183 (100)**	**4.8 (4.1-5.5)**
* injuries that required the full withdrawal of dance related activity as part of the overall severity				

3.3.2 Rank

All dancers were assigned a different rank for the entire year, which required different dancing demands. The male principles, first artists and artists all experienced a much higher incidence of injury compared with the soloists ($p<0.05$), while for female dancers the artists experienced the highest incidence which was significantly higher than female Principals and 1st Artists ($p<0.05$). The severity per dancer was highest for female artists (29 days absence per dancer) and soloists (28 days absence per dancer) and male 1st Artists (125 days absence per dancer) and principals (121 days absence per dancer) (Table 3.6). Pearson's correlation of age and incidence was -0.200 with a p-value of 0.160. Pearson's correlation of age and number of injuries was -0.190 with a p-value of 0.177.

Table 3.6: The Incidence, Severity and Full Day's Absence of Injuries as a Function of Gender and Rank

Rank	**Female**					**Male**				
	Number of dancers	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)	Number of dancers	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)
Principal	4	20 (11)	3.3 (2.1-5.0)	5 (3.10-7.44)	16 (10.07-24.20)	4	32 (17)	5.2 (3.7-7.4)	15 (10.67-21.34)	48 (34.2-68.3)
Soloist	7	45 (26)	4.2 (3.1-5.6)	4 (3.29-5.89)	18 (13.74-24.65)	4	7 (4)	1.1 (0.5-2.4)	2 (1.02-4.49)	1 (0.16-0.68)
1st Artist	5	18 (11)	2.3 (1.5-3.7)	5 (3.01-7.58)	11 (7.05-17.06)	5	45 (25)	5.9 (4.4-7.8)	14 (10.35-18.57)	37 (27.7-49.7)
Artist	11	89 (52)	5.3 (4.3-6.5)	4 (2.88-4.36)	19 (15.14-22.93)	12	99 (54)	5.4 (4.4-6.5)	6 (9.94-7.33)	2 (1.29-1.91)
All dancers	**27**	**172 (100)**	**4.1 (3.6-4.8)**	**4 (3.48-4.69)**	**17 (14.42-19.45)**	**25**	**183 (100)**	**4.8 (4.1-5.5)**	**9 (8.12-10.85)**	**16 (13.80-18.44)**

3.3.3 Activity

Although data was collected regarding all injuries sustained by company dancers, only injuries sustained within the measurable dance related exposure activities were included in this study; non-dance onset injuries were removed from this analysis. Dancers performed in 145 performances of 15 different shows, spread in blocks of between 2 and 6 weeks over the performance year, averaging 7 performances per week during performance weeks. Training (rehearsal and class) took place throughout the year (excluding holiday periods) for 6 days of the week including during performance periods. The dancers had a one week mid-season break and a further 5 week break over the summer. The average number of dance hours per week (performance and practice) was 36 hours. Both female and male dancers experienced the highest incidence of injury during class and the lowest during rehearsal. Performance accounted for significantly greater ($p<0.05$) time lost for female (47%) dancers with an average severity of 7.41 days per injury, while rehearsal accounted for the lowest percentage of time lost in female (23%) and male dancers (17%) with an average severity 2.36 days and 4.27 days lost per injury respectively. Male dancers recorded the highest percentage time loss in class (53%) with an average severity of 13.45 days per injury (Table 3.7).

Table 3.7: The Incidence, Severity and Full Day's Absence of Injuries as a Function of Activity

	Female				Male			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)
Class	46 (33)	4.9 (3.7-6.6)	4 (2.87-5.11)	19 (14.15-25.23)	65 (38)	7.5 (5.9-9.6)	13 (10.54-17.15)	101 (79.46-129.22)
Rehearsal	58 (41)	2.4 (1.9-3.1)	2 (1.83-3.06)	6 (4.44-7.42)	66 (39)	3.0 (2.3-3.8)	4 (3.36-5.44)	13 (10.02-16.24)
Performance	37 (26)	4.4 (3.2-6.1)	7 (5.37-10.22)	33 (23.87-45.48)	40 (23)	5.2 (3.8-7.1)	13 (9.17-17.04)	65 (47.63-88.53)
ALL INJURIES	**141 (100)**	**3.4 (2.9-4.0)**	**4 (5.53-4.91)**	**14 (11.99-16.68)**	**171 (100)**	**4.5 (3.8-5.2)**	**10 (8.34-11.25)**	**43 (37.10-50.07)**

3.3.4 Recurrent Injuries

Female dancers experienced a significantly ($p<0.05$) higher incidence of first episode injuries (49%) and recurrences (40%) but less exacerbations (11%) while first episodes represented the greatest percentage of time loss (55%), with recurrences accounting for 34% and exacerbations 11%. Male dancers recorded a significantly higher ($p<0.05$) incidence of exacerbations (58%). First episodes (10%) accounted for a significantly higher amount of time loss ($p<0.05$) in male dancers (Table 3.8).

Table 3.8: The Incidence, Severity and Full Day's Absence of Injuries as a Function of Gender and Episode

	Female dancers			**Male dancers**		
	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)
First-Episode	2.0 (1.7-2.5)	5 (3.65-5.59)	9 (7.48-11.45)	0.5 (0.3-0.8)	59 (37.67-92.58)	29 (18.63-45.78)
Exacerbation	0.5 (0.3-0.7)	4 (2.52-6.19)	2 (1.15-2.83)	2.8 (2.3-3.3)	2 (1.71-2.50)	6 (4.71-6.89)
Recurrence	1.6 (1.3-2.1)	4 (2.74-4.40)	6 (4.48-7.21)	1.5 (1.2-1.9)	7 (5.03-8.41)	10 (7.59-12.69)

3.3.5 Injury Type and Causation

Similar incidence rates were recorded for females (2.8 /1000hrs dance related activities) and males (2.9/1000hrs) overuse injuries, while a difference between females (1.3 /1000hrs) and males (1.9/1000hrs) traumatic injuries was noted (Figure 3.1). Overuse injuries accounted for 68% of female and 60% of male injuries and resulted in 54% and 58% of time loss, respectively and was statistically greater in incidence and severity than traumatic injuries ($p<0.05$) in both female and male dancers. Female overuse injuries resulted in 378 days and traumatic injury resulting in 317 days where performance was limited in relation to 1005 days and 713 days for male dancers for overuse and traumatic injuries respectively (Figure 3.2).

Relating to the nature of injuries (Table 3.9), similar extrinsic figures were recorded for females (1.5/1000hrs) and males (1.6/1000hrs), with a greater difference noted in the incidence of male intrinsic injuries (3.1/1000hrs) over the females (2.7/1000hrs). Intrinsically related injuries accounted for the both the majority of injuries (female 64%; male 66%), as well as the greatest percentage of days absence (female 70%; male 80%).

The difference in injury incidence and severity was statistically significant (p<0.05) in both male and female dancers.

Figure 3.1: The Incidence of Traumatic and Overuse Injuries as a Function of Gender

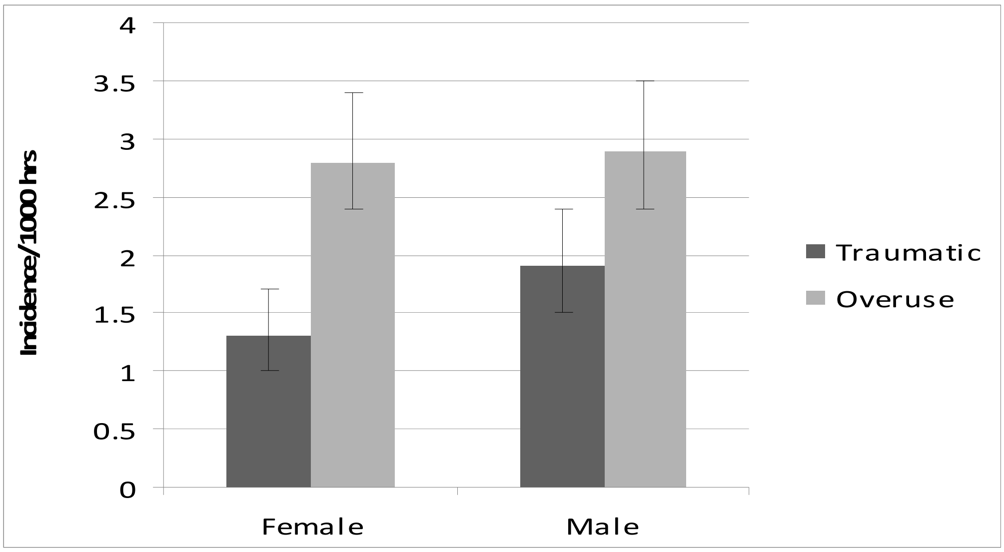


Figure 3.2: The Severity of Traumatic and Overuse Injuries as a Function of Gender

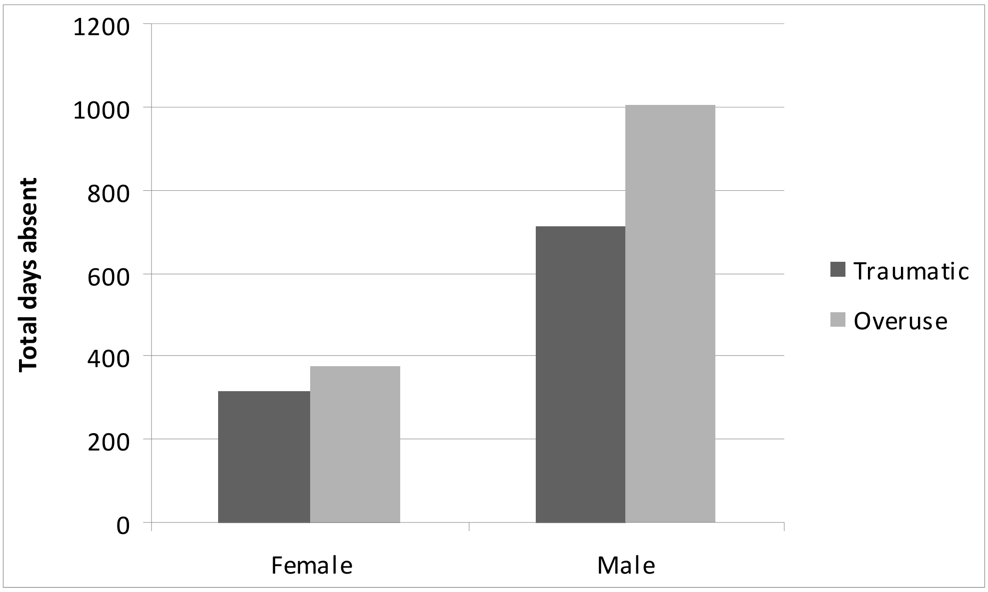


Table 3.9: The Incidence, Severity of Injuries as a Function of Gender and Causation

	Female				**Male**			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)
Extrinsic	62 (36)	1.5 (1.2-1.9)	3 (2.60-4.28)	5 (3.89-6.40)	63 (34)	1.6 (1.3-2.1)	5 (4.18-6.85)	9 (6.85-11.23)
Intrinsic	110 (64)	2.7 (2.2-3.2)	4 (3.68-5.35)	12 (9.75-14.18)	120 (66)	3.1 (2.6-3.7)	12 (9.62-13.76)	36 (30.05-42.98)

3.3.6 Mechanism of injury

A large number of injuries were classified as "cannot recall" (19%) or "other" (21%). Outside of these the largest proportion of injuries were sustained during jumping activities, with small jumps accounting for 9.9% of all injuries, and middle jumps accounting for 5.9% and large jumps accounted for 9% of injuries. Performing arabesque accounted for 7.1% of injuries while lifting accounted for 5.9% and Pointe work accounted for 5.2% of injuries sustained.

3.3.7 Body and Injury Grouping

Looking at the incidence rates by body region (Table 3.10) and injury grouping (Table 3.11), the highest incidence of injuries occur within the lower leg, with Medial Tibial Stress Syndrome registering the highest injury incidences amongst this region. Both male and female dancers recorded high incidences of injuries from the ankle region, with ankle instability and sprains recording the highest incidences within the ankle region. Injuries were not limited to the lower extremities. The lumbar region recorded the 2nd highest injury incidence for females (0.65/1000hrs) and 3rd highest for males (0.57/1000hrs), with females having a predominance of facet related pathologies (0.29/1000hrs) and males recording more lumbar muscle based injuries (0.34/1000hrs). There was also a high incidence of injuries recorded from the head and neck region, with cervical facet joint pathologies the main reason. There were some gender specific findings in both body regions and injury groupings. Female dancers (0.43/1000hrs) showed a higher predominance of injury incidence from the foot region over the males (0.36/1000hrs) whereas males recording a much higher incidence of thoracic facet joint pathologies (0.34/1000hrs) compared to females (0.12/1000hrs). The highest (females: 10%) and second highest (males: 9%) percentage days absence within the injury groupings was recorded due to “ankle instability, ligament sprain, including sinus tarsi”, while the highest percentage day’s absence recorded for males was a result of stress fractures (35%), largely influenced by the presence of two anterior tibial cortex stress fractures.

Table 3.10: Injury Incidence for Female and Male Dancers' by Body Region, Number of Injuries and Incidence per 1000 hours of Dancing

	Female				Male			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)
Head and neck	22 (13)	0.53 (0.35-0.81)	4 (2.39-5.52)	2 (1.27-2.93)	18 (10)	0.47 (0.30-0.74)	5 (3.01-7.58)	2 (1.41-3.55)
Shoulder	1 (1)	0.02 (0.00-0.17)	2 (0.28-14.20)	0 (0.01-0.34)	11 (6)	0.31 (0.18-0.55	5 (3.03-9.39)	2 (0.95-2.93)
Arm and hand	1 (1)	0.02 (0.00-0.17)	2 (0.28-14.20)	0 (0.01-0.34)	0	-	-	-
Thoracic Spine and Rib	13 (7)	0.31 (0.18-0.54)	5 (2.90-8.61)	2 (0.91-2.70)	19 (10)	0.49 (0.32-0.78)	4 (2.22-5.45)	2 (1.10-2.69)
Lumbar Spine	27 (16)	0.65 (0.45-0.95)	4 (2.59-5.51)	2 (1.69-3.58)	22 (12)	0.57 (0.38-0.87)	5 (3.44-7.94)	3 (1.97-4.55)
Pelvis and Hip	12 (6)	0.29 (0.16-0.51)	3 (1.66-5.14)	1 (0.48-1.49)	8 (4)	0.21 (0.10-0.42)	5 (2.38-9.50)	1 (0.49-1.98)
Upper Leg	14 (7)	0.34 (0.20-0.57)	4 (2.58-7.36)	1 (0.87-2.48)	14 (8)	0.36 (0.22-0.62)	4 (2.50-7.12)	2 (0.91-2.59)
Knee	9 (5)	0.22 (0.11-0.42)	4 (2.20-8.11)	1 (0.48-1.76)	17 (9)	0.44 (0.28-0.71)	11 (6.73-17.41)	5 (2.98-7.70)
Lower Leg	30 (18)	0.72 (0.51-1.03)	4 (2.56-5.24)	3 (1.85-3.79)	35 (19)	0.91 (0.65-1.27)	23 (16.33-31.68)	21 (14.87-28.85)
Ankle	25 (14)	0.60 (0.41-0.89)	5 (3.11-6.81)	3 (1.87-4.10)	24 (13)	0.62 (0.42-0.93)	9 (5.81-12.93)	5 (3.63-8.08)
Foot	18 (10)	0.43 (0.27-0.69)	5 (2.98-7.50)	2 (1.29-3.25)	14 (8)	0.36 (0.22-0.62)	7 (4.31-12.30)	3 (1.57-4.48)
ALL INJURIES	**172 (100)**	**4.1 (3.6-4.8)**	**4 (3.48-4.69)**	**17 (14.42-19.45)**	**183 (100)**	**4.8 (4.1-5.5)**	**9 (8.12-10.86)**	**45 (38.68-51.68)**

Table 3.11: Injury Incidence for Female and Male Dancers' by Injury Grouping, Number of Injuries and Incidence per 1000 hours of Dancing

	Female				Male			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)
Cervical facet joint dysfunction /nerve root pathology	14 (8)	0.34 (0.20-0.57)	4 (2.07-5.91)	1 (0.70-1.99)	11 (6)	0.29 (0.16-0.52)	5 (2.77-9.03)	1 (0.79-2.58)
Neck muscle spasm/strain/tear	7 (4)	0.17 (0.08-0.35)	3 (1.36-5.99)	0 (0.23-1.01)	6 (3)	0.16 (0.07-0.35)	4 (2.02-10.02)	1 (0.32-1.56)
Shoulder muscle/ joint spasm/strain/tear/sprain	1 (1)	0.02 (0.00-0.17)	2 (0.28-14.20)	0 (0.01-0.34)	5 (3)	0.31 (0.18-0.55)	5 (3.03-9.39)	0 (0.21-1.19)
Other head/neck/arm pathology	1 (1)	0.02 (0.00-0.17)	2 (0.28-14.20)	0 (0.01-0.34)	9 (5)	0.05 (0.01-0.21)	3 (0.75-12.00)	1 (0.33-5.31)
Thoracic facet joint/ rib dysfunction	5 (3)	0.12 (0.05-0.29)	9 (3.66-21.14)	1 (0.44-2.55)	13 (7)	0.34 (0.20-0.58)	4 (2.19-6.49)	1 (0.74-2.20)
Thoracic muscle spasm/strain/tear	8 (5)	0.19 (0.1.-0.39)	3 (1.31-5.25)	1 (0.25-1.01)	5 (3)	0.13 (0.05-0.31)	3 (1.25-7.21)	0 (0.16-0.94)
Lumbar facet joint dysfunction/ nerve root pathology	12 (7)	0.29 (0.16-0.51)	6 (3.12-9.68)	2 (0.90-2.80)	5 (3)	0.13 (0.05-0.31)	5 (1.91-11.05)	1 (0.25-1.44)
Lumbar muscle spasm/strain/tear	11 (6)	0.27 (0.15-0.48)	2 (1.31-4.27)	1 (0.35-1.13)	13 (7)	0.34 (0.20-0.58)	6 (3.75-11.13)	2 (1.27-3.76)
Lumbar pain undiagnosed	3 (2)	0.07 (0.02-0.22)	6 (1.83-17.57)	0 (0.13-1.27)	3 (2)	0.08 (0.03-0.24)	2 (0.65-6.20)	0 (0.05-0.48)
Gluteal/Hip(incl psoas) muscle spasm/strain/tear	8 (5)	0.19 (0.10-0.39)	3 (1.31-5.25)	1 (0.25-1.01)	5 (3)	0.13 (0.05-0.24)	3 (1.42-8.17)	0 (0.18-1.06)
Thigh muscles spasm/strain/tear	20 (12)	0.48 (0.31-0.75)	4 (2.55-6.12)	2 (0.91-3.99)	19 (10)	0.49 (0.32-0.78)	4 (2.82-6.93)	2 (1.04-4.58)
Knee joint/ligament derangement	8 (5)	0.19 (0.10-0.39)	5 (2.25-9.00)	1 (0.33-2.31)	16 (9)	0.42 (0.26-0.68)	11 (6.97-18.57)	5 (2.26-9.93)
Peroneal tendinosis	4 (2)	0.10 (0.04-0.26)	3 (1.22-8.66)	0 (0.12-0.83)	0	-	-	-
Medial Tibial Stress Syndrome	11 (6)	0.27 (0.15-0.48)	4 (2.16-7.06)	1 (0.57-1.87)	11 (6)	0.29 (0.16-0.52)	10 (5.69-18.55)	3 (1.63-5.31)
Stress fracture incl tibia/metatarsal	0 (0)	-	-	-	4 (2)	0.10 (0.04-0.28)	150 (56.20-399.00)	16 (5.85-41.54)

	Female				Male			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Average Severity (Days) (95%CI)	Days absence/ 1,000 hrs dancing (95%CI)
Tibialis posterior tendinosis	9 (5)	0.22 (0.11-0.42)	3 (1.56-5.77)	1 (0.34-1.25)	5 (3)	0.13 (0.05-0.31)	5 (2.25-12.97)	1 (0.29-1.69)
Calf muscle spasm/strain/tear	7 (4)	0.17 (0.08-0.35)	4 (1.91-8.39)	1 (0.32-1.42)	15 (8)	0.39 (0.24-0.65)	4 (2.57-7.08)	2 (1.0-2.76)
Lower leg pain undiagnosed	10 (5)	0.24 (0.13-0.45)	3(1.61-5.58)	1 (0.39-1.34)	4 (2)	0.10 (0.04-0.28)	2 (0.84-6.00)	0 (0.09-0.62)
Achilles tendinopathy	0 (0)	-	-	-	1 (1)	0.03 (0.00-0.18)	13 (1.83-92.29)	0 (0.05-2.40)
Ankle instability/ ligament sprain incl. sinus tarsi	11 (7)	0.27 (0.15-0.48)	6 (3.47-11.33)	2 (0.92-3.00)	11 (6)	0.29 (0.16-0.52)	13 (7.40-24.13)	4 (2.12-6.91)
Ankle impingement/jarring/ joint capsule sprain	2 (1)	0.05 (0.01-0.19)	3 (0.88-13.99)	0 (0.04-0.67)	6 (3)	0.16 (0.07-0.35)	7 (3.14-15.58)	1 (0.49-2.43)
Ankle pain undiagnosed	5 (3)	0.12 (0.05-0.29)	2 (0.83-4.81)	0 (0.10-0.58)	3 (2)	0.08 (0.03-0.24)	2 (0.75-7.23)	0 (0.06-0.56)
Foot muscle spasm/strain/tear	9 (5)	0.22 (0.11-0.42)	6 (3.12-11.53)	1 (0.68-2.50)	7 (4)	0.18 (0.09-0.38)	3 (1.43-6.29)	1 (0.26-1.15)
Sprain foot/toe joint	0 (0)	-	-	-	3 (2)	0.08 (0.03-0.24)	18 (5.91-56.84)	1 (0.46-4.44)
1^{st} Metatarsophalangeal jt pain	6 (3)	0.14 (0.06-0.32)	5 (2.32-11.50)	1 (0.34-1.66)	3 (2)	0.08 (0.03-0.24)	3 (0.97-9.30)	0 (0.08-0.73)
ALL INJURIES	**172 (100)**	**4.1 (3.6-4.8)**	**4 (3.48-4.69)**	**17 (14.42-19.45)**	**183 (100)**	**4.8 (4.1-5.5)**	**9 (8.12-10.85)**	**45 (38.68-51.68)**

3.4 Discussion

3.4.1 Incidence

The purpose of the study was to report the incidence, severity and aetiology of injuries sustained by a cohort of professional ballet dancers. The data reported an injury incidence of 4.4/1000hrs. This is the first study in dance to use a prospective study consistent with the recommendations of the various consensus statements on injury data collection in sport (Fuller et. al. 2006; Fuller et. al. 2007; Pluim et. al. 2009). In the absence of a similar consensus in data collection in dance alongside the call from the two published systematic reviews to provide explicit definitions and methodologies (Hincapie et. al. 2008; Jacobs et. al. 2012) the decision was made to adopt the sports consensus methodology. As the injury definition and methodology was consistent with other seminal papers in injury incidence in sport, a cross comparison is possible, allowing for an understanding of the relative risks of participation in the variety of physical activities. This comparative ability may also assist healthcare providers in understanding the level of health care provision needed by comparing the relative injury incidence levels to other disciplines and how their healthcare is structured to support those needs. While every effort was made to control aspects of bias, threats to the validity of these findings do need to be considered. This study has a number of limitations. The sample size needed for precision and confidence in estimates of effects was greater than available within this sample of convenience. The reliability and validity of the injury surveillance tool was not established. Due to the decision to implement this tool within a high performance environment, it was decided to utilise the same data collection process from a seminal study on injury surveillance in high performance sport (Brooks et. al. 2005a,b) to improve confidence in the outcomes. In addition, a standardised injury data collection form was developed that replaced initial-contact medical records. One perceivable weakness of this method could be the failure for dancers to report those injuries which result in not being able to continue with all activities but to continue in a restricted capacity. Author bias needs to be considered due to the main author also being the principal researcher who was not blinded to the data being collected. Author bias in injury diagnosis may also be perceived as a limitation. The use of international injury diagnosis codes (OSICS) and weekly injury meetings with medical staff were used to reduce reporting bias. The use of estimated exposure may be a further limitation. Measured individual exposures would enhance our understanding of the challenges of dance and enable more confidence to provide suitable solutions to issues in the future. Although the company in question has a consistent repertoire and the amount of dance related activity is determined by the dancers' union contractual regulation, along with consistent dancer numbers in the three years preceding this study, it is also acknowledged that the sampling of data over one year may affect the level of precision and that extending the period of study could enhance the confidence in trends observed

The professional ballet dancers in the current study experienced an incidence of injury (4.4 injuries per 1,000 dancing hours) that was towards the upper end of the range of incidence figures reported in previous epidemiological studies of ballet dancers' injuries (0.62-5.6/1000hrs)(Gamboa et. al. 2008, Luke et. al. 2002, Nilsson et. al. 2001 Leanderson et. al. 2011). However, the wide variety of injury definitions used and the methodological deficiencies and inconsistencies mean that the figures and findings are not accurately comparable. The time-loss injury definition used in the current study required injuries that directly impacted on dancers´ ability to perform in dance related activities to be reported. International consensus within other sports (Fuller et. al. 2006, Fuller et. al. 2007b) and the National Collegiate Athletic Association Injury Surveillance System (NCAA ISS)(Dick et. al. 2007a) has determined that a very similar definition should be utilised in injury epidemiology studies. Time-loss injury definitions have been widely used in many studies of other sports making inter-sport comparisons possible (Table 3.12). The current cohort of professional ballet dancers experienced a much lower incidence of injury (4.4/1000 hrs) than has been reported in many competitive sports such as rugby union (17/1000hrs)(Brooks et. al. 2005a) and soccer (8.5/1000hrs) (Hawkins and Fuller 1999) where aggressive physical contact and collisions with other competitors are frequent and/or part of the sport, but higher injury incidences in training sessions (female: 3.1/1000hrs; male: 4.3/1000hrs) than those reported in international football (2.8/1000hrs)(Hägglund, Walden and Ekstrand et. al. 2009) and elite rugby (2.0/1000hrs)(Brooks et. al. 2005b). The overall incidence of injuries recorded was greater than in elite volleyball (1.7/1000hrs)(Bahr and Bahr 1997) but slightly less than that of intercollegiate basketball (4.94/1000hrs)(Meeuwisse, Sellmer and Hagel et. al. 2003). In comparison with the more artistically focussed sport of gymnastics, an overall incidence of 22.7/1000hrs(Sands, Shultz and Newman et. al. 1993) and training (6.07/1000AE) and match (15.19/1000AE) incidences (Marshall et. al. 2007) are higher than recorded in this study, where one AE (athletic exposure) represented a single training session or match.

Table 3.12: The Incidence of Injury in Professional Sport using a Time-loss Injury Definition

Sport	Level of participation	Overall incidence	Training/rehearsal incidence	Match/Performance incidence
Ballet (current study	Elite	4.4/100hrs	3.1/1000hrs(female) 4.3/1000hrs(male)	4.4/1000hrs (female) 5.2/1000hrs (male)
Rugby (Brooks et.al. 2005)	International	17/1000hrs	6.1/1000hrs	218/1000hrs
Rugby (Brooks et.al. 2005a,b)	Elite	9.0/1000hrs	2.0/1000hrs	91/1000hrs
Football (Hagglund 2009)	International (Senior only)		2.8/1000hrs	41.6/1000hrs
Football (Hagglund 2006)	Elite		5.1/1000hrs# 5.3/1000hrs†	25.9/1000hrs# 22.7/1000hrs†
Football (Hawkins 1999)	Elite	8.5/1000hrs	3.5/1000hrs	27.7/1000hrs
Volleyball (Bahr and Bahr 1997)	Elite	1.7/1000hrs	1.5/1000hrs	3.5/1000hrs
Volleyball (female) (Agel 2007)	NCAA Division 1/2/3		4.10/1000AE*	4.58/1000AE*
Basketball (men) (Dick 2007)	NCAA Division 1/2/3		4.3/1000AE*	9.9/1000AE*
Basketball (female) (Agel 2007)	NCAA Division 1/2/3		3.99/1000AE*	7.68/1000AE*
Basketball (Meeuwisse et.al. 2003)	Intercollegiate	4.94/1000hrs		
Gymnastics (Sands 1993)	NCAA Division 1	22.7/1000hrs		
Gymnastics (Marshall 2007)	NCAA Division 1/2/3		6.07/1000AE*	15.19/1000AE*
Key: * 1 AE represents 1 practice or competition session; # Season 1; †Season 2				

Professional ballet dancers perform many more hours of practice and performance per week (average of 36 hours a week in the current study) than professional athletes in many other competitive sports (Brooks et. al. 2005a, Brooks et. al. 2005b, Hawkins and Fuller 1999). Consequently, despite the disparity in the incidence figures, dancers still received an average of 6.8 injuries per year, more than the 2.1-5.39 injuries per year per player reported in football (Hawkins and Fuller 1999, Peterson, Junge, Chomiak, et. al. 2000) or 1.92 injuries per player per season in rugby union (Brooks et. al. 2005a, Brooks et. al. 2005b). Furthermore, all of the dancers in the current study sustained at least one injury during the year and a total of 355 injuries (average of 7.7 injuries per week based on a 46 week working year) causing 660 days absence from full participation (average of 14 days lost per week based on a 46 week working year). It would therefore appear prudent to encourage the implementation of injury prevention and therapeutic interventions in an attempt to reduce the impact of these injuries, and also to continue to monitor injury epidemiology via on-going injury surveillance (Fuller and Drawer 2004, van Mechelen et al. 1992). Improving medical support and encouraging a greater focus on injury prevention have been shown to have a positive impact on the rate of injuries in dancers previously (Solomon et. al. 1999, Bronner et. al. 2003).

3.4.2 Reliability

In order to improve the reliability of recorded injuries for this type of injury definition, a system was employed where the standardised injury surveillance form replaced the initial injury assessment form in the medical records of the dancers within the company, so that all injury's that resulted in planned activities having to be modified would be recorded. The one perceivable weakness of this method could still be those injuries which result in a dancer not being able to continue with all activities planned but fail to report this to the medical staff. With an in-house medical team, bound by medical confidentiality and data protection acts, so that no information could be communicated to the ballet management team regarding any injury that may affect their ability to be cast or perform unless consent from the dancer had been explicitly given, it was expected that if this situation did exist, it would represent a very small proportion of the injuries recorded. This is supported by the fact that all members of the company at some stage of the study recorded an injury, suggesting that the dancers have confidence in the system employed at this company. The use of international injury diagnosis codes (Orchard 1993) and weekly injury meetings with medical staff was used to reduce reporting bias.

3.4.3 Injury Definition

Meeuwisse and Love (1997) while advocating the need to allow for restricted activities to be included in the time-loss injury definition, point out that the distinction between partial or complete restriction of activity is not always made. While severity in days will allow an understanding of the impact of an injury on performance, understanding the distinction between full and partial restriction of activity within the injury episode gives a more in-depth appreciation as to the impact of injury. It also allows the clinician to evaluate whether a more prolonged period fully withdrawn from activities may benefit an overall severity period, or whether advocating patients to continue in a restricted capacity allows a quicker return to full activities. This study allowed the amount of time within the overall severity where a full restriction of dance related activities existed to be noted. Of the injuries recorded, 13% of female dance injuries and 20 % of male dance injuries resulted in a full withdrawal from any dance related activity as part of their overall severity period. This supports the need for a more encompassing time loss injury definition as a larger percentage of injuries in dance do not require a full withdrawal from dance related activities and such would be missed with less encompassing injury definitions. As part of a longer epidemiological study it will also provide a means for further evaluation of the decision making as to whether allowing dancers to continue with some form of dance related activity may have a positive or negative effect on their severity period/return to full dance activity.

3.4.4 Rank

The type of the role a dancer may perform within a particular choreography can be largely determined by the rank they hold within the company. The principals will perform the major roles which may entail both partnering, where the males would be required to perform lifts and support the female dancer in various poses, as well as high intensity dancing and jumps. Soloists tend to fall into two categories. Some develop into performing more “character” roles that require a greater artistic interpretation but may not be as physically challenging. Other soloists can be younger members of the company who have been identified as potential principal level dancers and may find themselves cast into principal roles, with the physical demands they entail. First artists and artists, make up the core of the ballet or “Corp de Ballet”. They may be required to stand or sit for prolonged periods of time as part of the background of a scene, followed by a bout of dance, normally as part of a larger group. The Corp males may be required to perform some partnering lifts, but these tend not to be as individuals but more as a part of a group of two or three male Corp dancers.

When examining the results of the injury incidence by rank, the male principal dancers recorded an injury incidence of 5.2/1000hrs. This may be in part due to their workload and nature of the roles male principals undertake, with intense periods of "solo" dance pieces coupled with supporting and lifting partners in "pas de deux". But this figure is higher than their female counterpart (4.1/1000hrs). There is also a significant ($p<0.05$) difference between the injury incidence between the male soloists (1.1/1000hrs) and the rest of the males, as well as in comparison with the female soloists (4.2/1000hrs). It may be influenced by the fact that within the Company at the time, the main core of the male soloist dancers had developed into more character dancers, meaning that the bulk of the principal roles were being undertaken by the principal dancers, with some of the identified talented young 1st artists being given the opportunity to dance principal roles. This may also explain the higher incidence of injury noted among the male 1st artists (5.9/1000hrs) against the female 1st Artists (2.3/1000hrs). It is noted that the Artists in both male and female groups, incorporating the younger members of the company, register the highest (female) and second highest (male) injury incidences within the gender groups. Artists join the company following their training from full-time vocational schools. The transition from school to professional dancer can provide a number of challenges. These include continuing to develop the technical expertise needed as well as achieving the strength and fitness to respond to the demands placed upon them at the professional level. Within the dance related literature only one paper reported the relationship between injuries and rank (Solomon et. al. 1999). Their findings are reported with both genders combined and as a percentage of the overall injury numbers as opposed to injury incidence and are based on retrospective survey of medical records. The figures over the five year injury survey period indicate the Corp de Ballet group record the highest percentage of injuries. They do, however, represent the largest group amongst the ranks.

3.4.5 Activity

The three main dance related activities undertaken at this Company are class, rehearsal and performances. Class is performed 6 days a week for 1hour 15 minutes, and forms part of the dancers technical and skill acquisition, conditioning, and general preparation for the days scheduled activities. Here males recorded a higher incidence of injuries (7.5/1000hrs) in comparison to the female dancers (4.9/1000hrs). Rehearsal recorded the lowest incidence of injuries among both male (3.0/1000hrs) and female (2.4/1000hrs) dancers within the dance activity groups, where activities tend to be less physically intense and there are frequent breaks for explanations and directions from choreographers (Wyon, Head, Sharp, et. al. 2004). Performances related injury incidence was lower than class related injury incidence for both males (5.2/1000hrs) and females (4.4/1000hrs). The lower injury incidence recorded during rehearsal may be related to the fact it is an environment where in the early stages there will be a learning process that would be physically less intense. When reporting the activity in which injuries were sustained in sport, activities are often classified as either training or matches. When class and rehearsal incidences are combined into a single category of training (female: 3.1/1000hrs; male: 4.3/1000hrs), this study displays a higher injury incidence sustained during performances versus training (female: 4.4/1000hrs; male 5.2/1000hrs). This is similar to that is seen in other sports in reporting injuries sustained during matches versus training (Agel et al. 2007a, Bahr and Bahr 1997, Dick et al. 2007b, Marshall et al. 2007) although this difference is not as great as the difference that is seen in rugby (training: 2.0/1000hrs; match: 91/1000)(Brooks et al. 2005a, Brooks et al. 2005b) and football (training: 3.5/1000; match 27.7/1000)(Hawkins and Fuller 1999).

3.4.6 Recurrence

It is recognised that a previous injury can increase the risk of sustaining a similar injury in the future (Bahr and Bahr 1997) and as such, with risk assessment and management as part of the objective of injury surveillance, it is important to record the nature of each injury episode. Female dancers within this study recorded 2.0/1000hrs first episode injuries, with 0.5/1000hrs exacerbations, and 1.64/1000hrs recurrent injuries. Male dancers recorded a first injury rate at 0.5/1000hrs, an exacerbation rate of 2.8/1000hrs and a recurrent rate of 1.51/1000hrs. The reason for a higher exacerbation rate could be linked to the injury definition used. Injuries were reported on a daily basis by 3 in-house full-time physiotherapists. The advantage of this was that dancers would often attend "treatment" sessions with musculoskeletal complaints that they were aware of but did not at that stage limit their performance. If and when these complaints impacted on the dancers' ability to perform, then these injuries could easily be reported as an "injury". The high number of exacerbation injuries recorded reflects the change in status of those injuries that initially started as not restricting working capacity to an "injury status" where a limitation on participation in required activities was reported. The average severity in days of recurrent injuries was 3.47 for females and 6.50 for males, which was lower than 1st episodes, a factor which is different to some sports papers (Brooks et. al. 2005) The international consensus statement on injury definitions and data collection in football injuries (Fuller et. al 2006) delineated the definitions of recurrence to include "early recurrence" as those injuries that occurred within two months of the players return to full participation, "late recurrence" as those injuries that occurred between 2 and 12 months after a players return to full participation, and "delayed recurrence", where an injury was reported to have reoccurred more than 12 months after a player had returned to full activities. In proposing a uniform reporting system for professional dance companies, Bronner et.al. (2006), suggests using 2 months as the time limit for deciding whether an injury constitutes a recurrence, and that those injuries that result in the same diagnosis as the index injury but occur at a time greater than 2 months be classified as a new injury to avoid recall bias. This study elected to maintain a definition of recurrence as one that occurred of the same type and at the same site as the first episode injury, occurring after a player's return to full participation from the index injury within one year. The nature of the medical records used within this company allows for easy referral to previous injuries to ascertain if an injury would constitute a recurrent injury and therefore avoid recall bias. The adoption of this definition of injury would allow the results of the injury surveillance to give a true and longer term picture of the effectiveness of intervention and rehabilitation of dancers' injuries.

3.4.7 Injury Type and Causation

Part of risk assessment in sport or dance is identifying risk factors. This then is used to determine the impact on those participants. Risk factors can be categorised as intrinsic or extrinsic (Fuller and Drawer, 2004, Bahr and Holme, 2003, van Mechelen et.al., 1992, Meeuwisse, 1991). Intrinsic factors are considered to be those specific to an individual participant, and can include strength and joint stability etc., whereas extrinsic factors arise from external sources, and would include surfaces, protective equipment etc. (Fuller and Drawer, 2004). It is recognised through injury causation models that there is an interaction of intrinsic and extrinsic factors that result in an injury (Meeuwisse 1994, Bahr and Holmes 2003, Meeuwisse et.al. 2007). Within this study, an evaluation was made by the clinician as to whether the injury was a result of an intrinsic or extrinsically related causation factor through the medical history, reporting of the inciting event, or mechanism of injury. The nature of the injuries recorded in this study suggest that a greater risk may result from intrinsic causation factors, with both female and male dancers recording higher intrinsic incidences (2.7/1000hrs and 3.1/1000hrs respectively) than extrinsic incidences (1.5/1000hrs and 1.6/1000hrs respectively). This provides, albeit from a low level of evidence due to the observational methodology and reporting bias in classification, support for considering interventional strategies towards reducing injury incidence using an intrinsic focus. The presence of highly repetitive movements in both the training and the performances in dance would support the higher incidence of overuse injuries noted in dance (Bronner et. al. 2003; Luke et. al. 2000; Nilsson et. al. 2001; Shah 2008; Solomon et. al. 1995; Solomon et. al. 1999). This study supports that premise, with both male and female dancers recording a greater incidence of overuse injuries compared with traumatic injuries (female: overuse 2.82/1000hrs, traumatic 1.37/1000hrs; male: overuse 2.84/1000hrs, traumatic 1.93/1000hrs). Traumatic injuries that resulted in a greater average severity for both female (overuse: 3 days; traumatic: 6 days) and male dancers (overuse: 9 days; traumatic: 10 days), the risk as a product of incidence and severity (severity per 1000hrs) indicated higher values in overuse injuries for female (overuse: 9 days /1000hrs; traumatic: 8 days/1000hrs) and male dancers (overuse: 26 days/1000hrs; traumatic: 19 days/1000hrs).

3.4.8 Mechanism of injury

Within the sports literature the percentage or incidence of injuries relating to mechanism of injury has often been reported (Angel et. al. 2007; Brooks et. al. 2005; Dick et. al. 2007). Dance literature has often looked to links between specific injuries and mechanism of injury (Bowling 1989; Nilsson et. al. 2001; Quirk 1983; Wheeler 1987) In an attempt to understand the inciting event in this study, the injury history was used to describe how an injury occurred, with dancers asked what mechanism of injury they felt attributed to their injury from a list on the standardised assessment form. Although the majority of injuries were seen within 24 hours of the injury event, a high proportion of dancers failed to recall the inciting event. This supports the higher incidence of overuse injuries seen, where an individual episode may not be present. A proportion of dancers also felt that their mechanism of injury was not covered by the categories presented on the standardised list and therefore was classified as “other”. The purpose of a standardised list is to provide meaningful groups for analysis but as this list failed to capture a proportion of the mechanisms of injury further work needs to examine what omissions were identified on the list and need to be included for future study. Further to this, it was anticipated that activities like arabesque may not always be the cause of an injury, but rather the activity that exposed the limitation of their injury to their dancing capacity. The higher proportion of injuries relating to jumps would potentially be anticipated. The smaller jumps provide an increase loading in the lower leg muscles (Vuillerme et. al. 2002), while larger jumps incorporate greater ground reaction forces (Norcross et. al. 2010) both of which may increase overall fatigue and risk of injury (Wiesler et. al. 1996).

3.4.9 Body and Injury Groupings

A high proportion of lower limb (particularly to the lower leg, ankle and foot) and lumbar spine injuries, consistent with previous studies of ballet dancing injuries were reported (Gamboa et al. 2008, Garrick and Requa 1993, Milan 1994, Nilsson et al. 2001, Solomon et al. 1999). This would appear consistent with the demands placed on the lower limb from the technical aspects of ballet, coupled with the challenges on the lumbar region due to extreme ranges of movement required. The nature of work in ballet can be gender specific, with female dancers required to go “en pointe”, while male dancers are required to perform lifts. Breaking down the injuries recorded into body regions and injury groupings, there are some similarities noted between the genders, as well as some differences. Both male and female dancers recorded the highest injury incidence from the lower leg (0.91/1000hrs and 0.72/1000hrs respectively). Within the lower leg Medial Tibial Stress Syndrome (MTSS) reported among the highest and second highest injury grouping with 0.27/1000hrs and 0.29/1000hrs to female and male dancers respectively. The males’ highest injury grouping recorded related to calf muscle spasm/strain/tear, with an incidence of 0.39/1000hrs. The next highest body grouping category for female dancers is the lumbar region, recording an incidence of 0.65/1000hrs. Females recorded similar figures within the injury groupings between lumbar facet joint dysfunction or nerve root pathology (0.29/1000hrs) and lumbar muscle spasm/strain/tear (0.27/1000hrs). This is contrary to the male dancers where injuries to the ankle region constituted their second highest body grouping. Here male dancers recorded 0.29/1000hrs resulting from ankle instability or ligament sprain including sinus tarsi, and 0.16/1000hrs from ankle impingement/jarring or joint capsule sprain. Conversely, the third highest body grouping for female dancers was the ankle region, reporting an incidence of 0.60/1000hrs and, like male dancers, ankle instability or ligament sprain incl. sinus tarsi constituted the highest injury grouping at 0.27/1000hrs. The third highest body grouping for male dancers was the lumbar region, with lumbar muscle spasm/strain/tear recording the highest incidence within this region as 0.34/1000hrs and 0.13/1000hrs for lumbar facet joint dysfunction or nerve root pathology. The differences in the ranking of body regions and injury groupings may be related to the differences in the gender specific aspects of ballet. Female dancers have more requirements to perform arabesque, where increase loading and movement into lumbar spine extension will be sustained, potentially resulting in injuries to both the lumbar muscles and facet joints as reported here. The requirement of going “en pointe” may explain the slightly higher incidence of “foot muscle spasm/strains/tears” and “1st metatarsalphalangeal joint pain” in female dancers (Prisk, O'Loughlin, and Kennedy 2008, Russell, Shave, Yoshioka, et al. 2010, Wiesler, Hunter, Martin, et. al. 1996, Macintyre and Joy 2000, Milan 1994). Male dancers will be required to perform more lifts and partnering, which may increase the load on the lumbar muscles, resulting in the higher incidence seen. Male dancers recorded a higher rank and incidence for the thoracic spine/rib body grouping (0.49/1000hrs) in comparison with the female dancers (0.31/1000hrs). Here the males sustained 0.34/1000hrs within the thoracic facet joint or rib dysfunction grouping. This may be related to the lifting required within the male dancers’ repertoire. Both female and male dancers show ankle instability as the highest injury grouping within the ankle region, unsurprising considering the Pointe work and jumps dancers are required to perform. Both genders also noted relatively higher incidences of injuries to the head and neck region, where females recorded their fourth highest ranked body grouping as 0.53/1000hrs, and males their 5th highest body grouping ranking as 0.47/1000. With cervical facet joint dysfunction or nerve root pathology, with incidences of 0.34/1000hrs and 0.29/1000hrs for female and male dancers respectively, the more common injuries noted from this body region.

The correlation between age and injury has been inconsistent in the dance literature. (Bronner et. al. 2003). In a study of Broadway performers, a link between higher age and injury is suggested (Evans et. al. 1996). A further study reported dancers older than 25 years of age recording greater shoulder and foot and ankle injuries (Ramal and Moritz 1994). While other studies have reported a greater incidence of ankle injuries and stress fractures of the foot in younger dancers (Nilsson et. al. 2001) or the 21-25 year category (Solomon et. al. 1995). Within this study there were no correlations were noted between age and injury incidence or injury numbers. This suggests that the demands placed on dancers in this company appear to be a greater predictor of injury than age and as such, considering rank/roles (or workload in particular) is an important part of considerations in injury prevention strategies.

3.5 Summary

Some of the achievement in sport can be attributed to the progression in sports medicine and the increased understanding of the needs of specific sporting populations, with epidemiological studies playing an important role in the understanding of those needs. Despite its extensive history the support of dance as an art form from a dance medicine perspective is still progressing with a lacking number of prospective studies into dance injuries available. The purpose of this study was to look at the incidence and severity of injuries of an elite ballet company over one year.

This study employed a prospective single cohort design. A time loss injury definition employed was chosen to allow data to be recorded from those injuries that may have not resulted in dancers having a full restriction in dance related activities. This allows for those injuries that dancers would continue to dance with, albeit it in a restricted capacity, to be accounted for. This information is critical to providing a full understanding of the true incidence of injuries in dance. In addition to this, the amount of days where full absence from any dance related activity was also recorded to allow the differentiation between partial and full withdrawal of dance related activities to be understood. The results obtained suggest a higher incidence of injuries than has been previously reported within some dance papers. This may be due to the different definition of injury used, and when only a full absence from any dance related activities was examined, the figures appear similar to other research undertaken. When examining the severity of injuries sustained, the higher incidences of less severe injuries noted with both male and female dancers suggest that it is important to record those “minor” injuries, as their relationship to the long-term sequelae of injury, as well as the impact on optimal performance levels cannot be ignored. Part of understanding risk is the determination of those intrinsic and extrinsic factors that can result in injury. Causation models in injury suggest that it is the interaction between intrinsic and extrinsic factors that ultimately result in the onset of an injury. It is still pertinent to establish the likeliest cause in each injury incidence in order for interventional strategies to be considered. The results of this study suggests that intrinsic factors play a larger role in the onset of injuries, and an interventional strategy aimed at addressing this could be implemented as part of the overall objective of reducing injuries in dance.

3.6 Conclusion

With a lack of quality injury data studies identified by two systematic reviews this study aimed to contribute to the understanding of dance injuries through the use of a single cohort prospective study of a professional ballet company that conformed to the recommendations of the various international consensus statements on injury data collection in sport. The results demonstrated an overall incidence of 4.4 injuries/1000hrs. The professional ballet dancers reported a high proportion of lower limb, lumbar spine and overuse injuries. Gender differences in injury incidence and profile were identified that may be explained by the different roles dancers perform. Noting the impact of injury in dance, a need to introduce interventions to reduce the risk of injury is apparent. While limited by author bias, its observational methodology and a small sample of convenience, the data obtained may be used by the in-house medical team to better inform services for dancers within the company.

Chapter 4: Injury Prevention

Data from this chapter has been published in Allen, N; Nevill, A; Brooks, J; Koutedakis, Y; Wyon, M (2013) The Effect of a Comprehensive Injury Audit Programme on Injury Incidence in Ballet: A 3-Year Prospective Study Clin J Sport Med. 2013 Sep;23(5):373-8. doi: 10.1097/JSM.0b013e3182887f32.

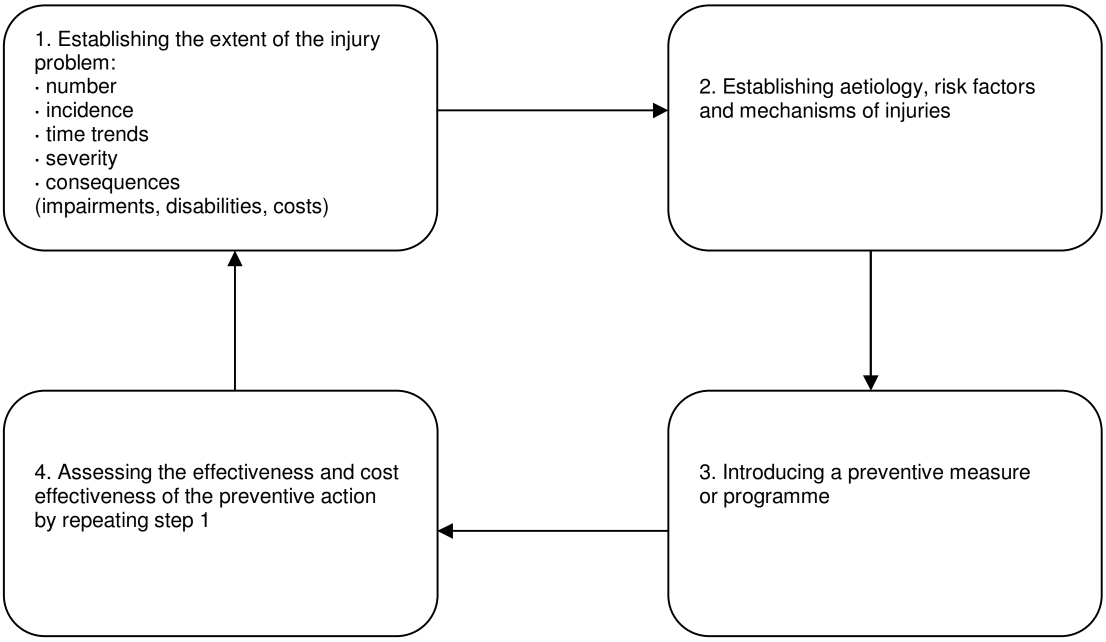
4.1 Introduction

Although the benefits of exercise are recognised, questions have been raised as to whether the benefits outweigh the risks of long term injury or disability (Ljungqvist, Jenoure, Engebretsen, et. al 2009). The impact of injury may affect both the individual dancer as well as their employer. Injury may have both financial and health ramifications, with short and long term implications. The financial ramifications of injury range from the costs of medical care to loss of personal income through withdrawal from performances. The time away from training and shows can lead to a performance deficit that could impact on the dance company's performance. Future contracts may also be adversely affected by injury history and status. Injury surveillance and epidemiological studies have been central to building an understanding as to the extent of injury rates within athletic pursuits through increased focus on the incidence and aetiology of injury. Through the understanding of the extent of injury, further development into medical and surgical management of these injuries can take place. While the importance of such improvements in the treatment of sports injuries is recognised, injury prevention is considered even more important (Engebretsen and Bahr, 2005). The results of the first year of the current study (Chapter 3), where an overall incidence of 4.4/1000hrs and risk of 33.5 days/1000hrs (calculated as a product of incidence and severity) was reported, highlights the need for injury prevention in this cohort of professional ballet dancers.

4.1.1 Injury Prevention Model

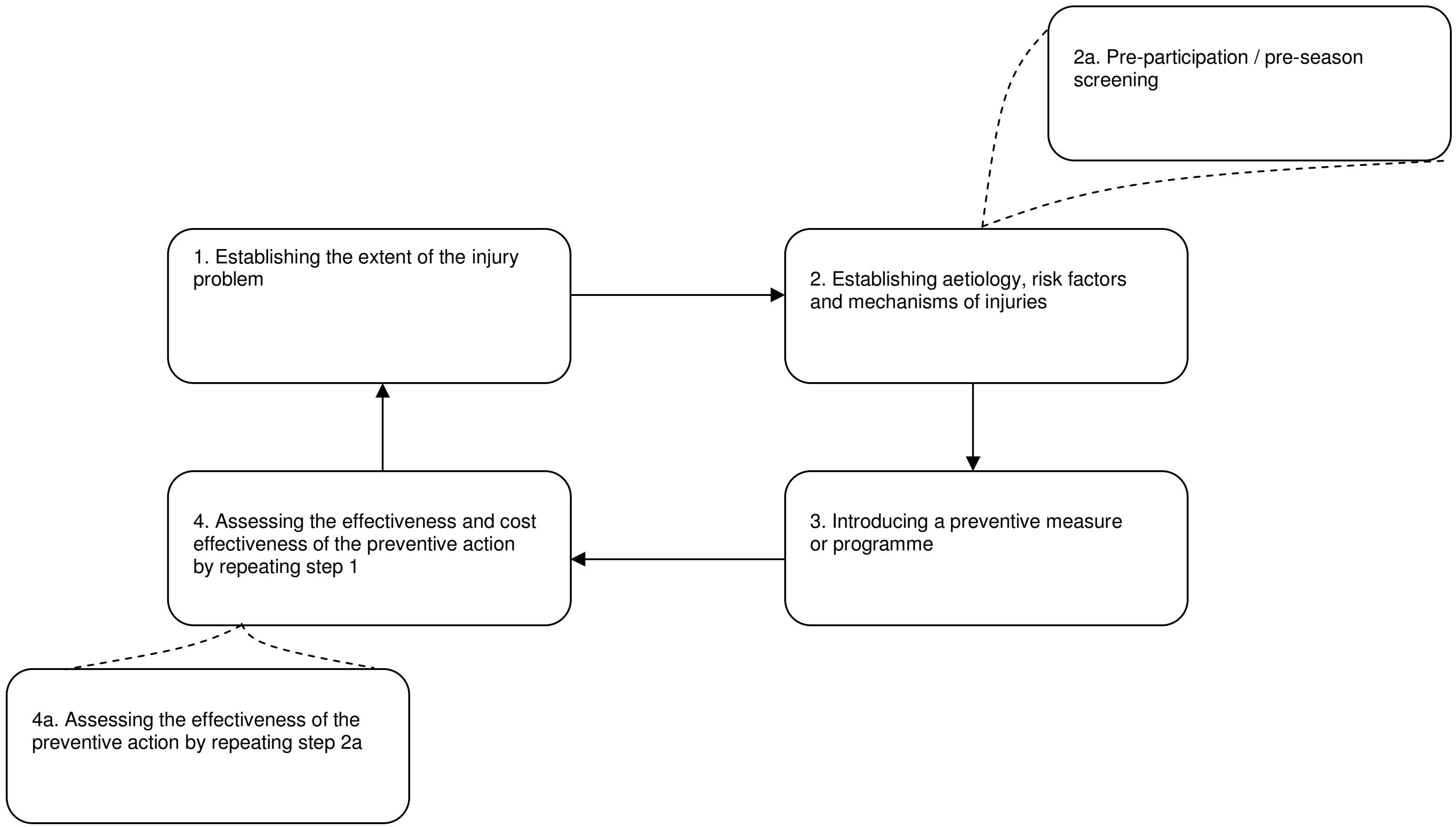
In Chapter 1, a recognised model for the prevention of injuries by van Mechelen, et. al. (1992) proposed a sequence of prevention of sports injuries (Figure 4.1). A fundamental component of this model arises from its first and second stages in understanding the extent of the sports injury problem by establishing its incidence and severity, as well as aetiology, risk factors and mechanism of injury, a process achieved through the undertaking of prospective epidemiological studies.

Figure 4.1: Injury Prevention Model Adapted from van Mechelen et. al. (1992)



The injury audit data is then used to establish the efficacy of any intervention strategies that may be implemented as a result. In order for step 3 to take place sensitive data regarding potential risk factors are needed. In the same way that it is important to establish the supporting data for the extent of injury problems, it is important that a similar system of data collection is undertaken to establish the extent of risk factors, in the form of intrinsic or extrinsic factors. Commenting on the traditional model of injury prevention, Bahr and Krosshaug (2005) indicate step 2 is critical in establishing the potential causes. An interpretation on the injury prevention model (Figure 4.2) sees the delineation of step 2 with the inclusion of the pre-season/pre-participation screen (step 2a). These data are then used in conjunction with the information gained in step 1 and 2 to introduce a preventative measure or programme (step 3). In the delineated model of injury prevention the assessment of the effectiveness of the interventional measure or programme (step 4) takes place in two parts. Within the original model the evaluation of its impact on the extent of injury is taken by repeating the injury audit process (step1). Further to this an evaluation can be made to ascertain any changes to the intrinsic risk factors determined by the screening process undertaken in step 2a by repeating this step. The added value of using this two-step approach is that it provides a greater understanding of the impact of an intervention programme on those identified intrinsic risk factors as well as the impact of other factors that may influence increased risk to injury.

Figure 4.2: Delineation of Injury Prevention Model from van Mechelen et. al. (1992)



4.1.2 Screening

Screening is the process whereby intrinsic factors such as previous injury, malalignment, muscle tightness, weakness, and joint range of movement are assessed as part of a strategy for injury prevention or performance enhancement (Fuller, Ojelade, and Taylor, 2007; Mottram and Comerford, 2008). The concept of screening is not new in dance, and experienced ballet teachers and choreographers have screened dancers for years (Siev-Ner, Barak, Heim, et. al. 1997). With the development of dance medicine and science, the screening process has been taken on by medical teams charged with the health and well-being of dancers. The aims of screening programmes in dance include: detecting and quantifying risk factors at an early stage; developing a baseline of body characterises for comparisons; to research the distinction between "normal" and variations of movement; uncovering pathology; and assessing the presence of necessary attributes needed for dance participation (Liederbach, 1997; Siev-Ner, et al., 1997).

The type and process of screening can vary considerably and can incorporate, among others, musculoskeletal assessments, fundamental movement patterns and dance specific testing.

4.1.2.1 Musculoskeletal Screening

Musculoskeletal screening has been used in general populations as a means to provide an early indication of possible pathologies (Beattie, Bobba, Wajsweiner, et. al., 2008). In the military it has been used effectively as a tool in providing information to reduce injury incidence and enhance performance prospects in an occupation where physical ability is critical (Petersen and Smith, 2007). A number of sports, including Australian football (Bennell, et. al. 1999), soccer (Bradley and Portas, 2007) and cricket (Dennis, et. al. 2008) have employed forms of pre-participation screening that encompass musculoskeletal aspects, including muscle power, length and joint range of movement (Gabbe, Bennell, Wajswelner, et. al. 2004). Bradley and Portas (2007) indicate the value of screening for range of movement in the lower extremities of elite level football players during preseason as a predictor of developing muscle injuries. The screening for particular foot postures in distance runners is indicated to have a predictive value in determining the onset of

Medial Tibial Stress Syndrome (Bennett, Reinking, Pluemer, et. al., 2001). Callaghan and Jarvis (1996) indicates how the development of medical screening, including a musculoskeletal assessment, for international elite cyclists has provided a means of providing early diagnosis for conditions that can be more effectively treated in the "off-season" to minimise the impact of these conditions on performance periods.

4.1.2.2 Combined Musculoskeletal and Sports Specific Screening

Some sports have utilised a combined approach to screening based on the specifics of their sport alongside a musculoskeletal assessment. The use of isokinetic testing of the knee and ankle and functional tests including shuttle runs, agility tests and jump tests have been used in soccer (Batt, Jaques, and Stone, 2004). Dennis, Finch, et. al (2008) used a combination of musculoskeletal and field based sports specific tests to identify risk factors for injury in fast bowlers in cricket. They indicated that only two of the thirty five tests performed had independent predictive value, these being musculoskeletal based tests for increased internal rotation of the hip and decreased ankle dorsiflexion. The use of a combined approach to screening appears prevalent in dance, where both musculoskeletal and dance specific attributes are assessed. Schon, Biddinger, and Greenwood, (1994); and Southwick and Cassella, (2002) indicate the results of a screening process that incorporates musculoskeletal aspects as well as dance specific has led to correction of identified problems, while Southwick and Cassella, (2002) reports improvement in key muscle groups as part of the Boston Ballet Student Screening Clinic using musculoskeletal and dance specific screening techniques.

4.1.2.3 Movement Screening

A further development in the screening process has seen the use of a more fundamental movement based screening modalities like the Functional Movement Screen (FMS) (Cook, Burton, and Hogenboom, 2006a, 2006b) and Performance Matrix (Comerford, 2006; Mottram and Comerford, 2008). The foundation of these approaches is based on the importance of assessing dynamic neuromuscular control including the site and direction of uncontrolled movement and its relative predictive value for injury and performance (Kiesel, Plisky, and Voight, 2007; Mottram and Comerford, 2008). The Functional Movement Screen, has been linked to prediction and prevention of injuries in military personnel (O'Conner et. al. 2011), female collegiate athletes (Chorba et. al. 2010), professional American Football (Kiesel, et al., 2007) and fire-fighters (Peate, Bates, Lunda, et. al. 2007). Advocates of movement screening suggest that testing of strength parameters, as in force or power, joint range or mobility, isolate individual joints in a non-functional situation (Comerford, 2006) and that testing for muscle length and joint range of movement have been relatively unsuccessful in predicting injury (Mottram and Comerford, 2008). Within any screening process, there is a need to understand segmental deficiencies and relate this further to its role within the movement system. This is achieved through appreciating the "regional interdependence" within the body, where dysfunction in one aspect of the body may contribute to weakness, tightness or pain in another aspect of the body (Minick, et. al. 2010, Wainner, Whitman, Cleland, et. al. 2007).

4.1.2.4 Issues in Screening: Reliability, Validity and Sensitivity

The validity of interventions as an outcome of the musculoskeletal assessment (and monitoring) as part of the screening system has been questioned over issues relating to poor sensitivity and specificity (Batt, et al., 2004). In the same way that an injury surveillance study needs to be well structured to ensure the reliability and validity of the outcomes, there is a need to apply the same rigors to the screening process if it is to provide information from which further interventions will be determined, as well as acting as a database to determine the effectiveness of those interventions (Bahr and Holme, 2003). In order to gain confidence in results of testing, the accuracy of measurements needs to be considered through intra- and inter-tester reliability (Dennis, Finch, Elliot, et. al., 2008; Gabbe, et al., 2004; Hayen, Dennis, and Finch, 2007; Minick, Kiesel, Burton, et. al., 2010). By ensuring good reliability the opportunity to retest the screening outcomes against previous results is strengthened. In combination, repeated measures data from the injury surveillance can enhance the understanding of the validity of screening in light of the objective of reducing injuries. Individual analysis of screening and injury data may also improve the understanding of sensitivity and specificity of screening and interventional approaches. Results for inter- and intra-reliability of musculoskeletal tests have been mixed. Gabbe et. al. (2004) suggest good inter-rater reliability and test-retest reliability for eight musculoskeletal tests (Sit and Reach, active knee extension, passive straight leg raise, slump, active hip internal rotation range of movement (ROM), active hip external ROM, lumbar spine extension ROM, and the Modified Thomas Test). Dennis, et al (2008) found that in similar musculoskeletal tests (knee extension, Modified Thomas Test, hip internal rotation ROM, hip external ROM, combined elevation, ankle dorsiflexion lunge, bridging hold, prone four point hold, and calf heel raises), that the inter-tester reliability was poor but the intra-tester reliability was of an acceptable level. Similar discrepancies in inter-tester reliability were noted by Batten, Taylor, Cook, et. al. (2010) when looking at the reliability of a number of musculoskeletal tests used in community level Australian Football (ankle dorsiflexion, supine passive hip internal rotation at 90deg, prone passive hip internal rotation, and quadriceps length). Excellent or substantial agreement was noted in the inter-tester reliability of the FMS using both expert and novice testers (Minick, et al., 2010, Onate et. al. 2012, Teyhen et. al. 2012) which is further influenced by clinical experience (Gribble et. al. 2013).

4.1.2.5 Exercise as Injury Prevention

The use of exercise programmes as part of preventative and treatment measures for injury has been explored in the literature with variable levels of evidence and success (Choi, Verbreek, Tam, et.al. 2010, Fransen and McConnell 2008, Fransen, McConnell, Hernandez-Molina et. al. 2009, Hayden , van Tulder, Malmivaara, et. al. 2005, Heintjes, Berger, Bierma-Zeinstra et. al. 2003, Kay , Gross, Goldsmith et. al. 2005, Trees , Howe, Dixon, et. al. 2005, Trees ,Howe, Grant et. al. 2007, Augustsson, Augustsson, Thomee et.al. 2006, Peate, et. al 2007, Fields, Sykes, Walker, et. al. 2010, Hupperets, Verhagen, Heymans, et. al. 2010, McGill 2010, Asplund and Ross 2010, Brushoj, Larsen, Albrecht-Beste, et. al. 2008 Sinibaldi and Smith 2007, Leiderbach 2010). The use of exercise as a means to prevent injury falls within the third step in van Mechelen's injury prevention model. The basis of exercise programmes can vary greatly from high threshold/resistance strength based exercise programmes (Vanekova, Ost'adal, Seidl, et. al. 2001) to low threshold proprioception based programmes (Bahr and Bahr 1997). There has been an increased focus into the role of "core stability" muscles and their role in preventing injuries (Keisel, et. al 2007, Mottram and Commerford 2008, Commerford 2006, Peate et. al 2007, McGill 2010, Asplund and Ross 2010, Leiderbach 2010). Core stability has been defined as "the ability of the lumbopelvic hip complex to prevent buckling and to return to equilibrium after perturbation" (Wilson, Dougherty, Ireland, et. al. 2005). The authors go on to say that "although static elements (bone and soft tissue) contribute to some degree, core stability is predominantly maintained by the dynamic function of muscular elements", and that there is a clear relationship between trunk muscle activity and lower extremity movement". What this definition provides is a description of how core stability works and the role it plays in providing support to a key body region within athletic movement. Mottram and Comerford (2008) expand on the term core stability with the more comprehensive term of "motor control stability" which is defined as "central nervous system modulation of efficient integration and low threshold recruitment of local and global muscles systems". A component of this may arise from neuromuscular control, which is defined as "the unconscious efferent response to an afferent signal regarding dynamic joint stability" (Mandelbaum, Silvers, Watanabe, et. al. 2005). The delineation of core stability to motor control stability and neuromuscular control allows the inclusion of body regions other than the lumbar pelvic region to be incorporated in the principal of providing stability for athletic performance.

Although the definitions are sometimes used interchangeably, the use of motor control stability, neuromuscular control and core stability has explored (Emery and Meeuwisse 2007, Grindstaff, Hammill, Tuzson, et al. 2006, Hewett, Ford and Myer 2006, Hubscher, Zech, Pfeifer, et. al 2010) and been suggested to be effective in the prevention of injuries and enhancing performance (Mandelbaum, et. al. 2005; Myer, Ford, Palumbo, et. al. 2005). Mottram and Comerford (2008) explain the differences between motor control stability control and strengthening with motor control stability being a "central nervous system modulation of efficient integration and low threshold recruitment of local and global muscles systems". The authors indicate strength training relates to "high load or high speed training of symmetrical limb loading and asymmetrical trunk loading". While there is evidence of the benefits of both systems, motor control stability can offer the achievement of local or global stability with stimulation of afferent spindle input affecting tonic muscle output via central nervous system process under a low load. This can provide the prospect of providing safer and potentially quicker protection against injury with lower risk of concomitant injury through the use of higher resistance loads, or the time to adaptation needed for hypertrophic/strength changes with traditional strength training

(Peterson, Rhea and Alvar 2005). Further to this, evidence has indicated that while high threshold training as used in traditional strength training does not appear to rectify motor control dysfunction (Moseley and Hodges, 2006; O'Sullivan, Twomey, and Allison, 1997), these can be corrected through the application of low threshold training (Hides, Jull, and Richardson, 2001; Jull, Trott, Potter, et al., 2002; O'Sullivan, 2000) like motor control stability.

Neuromuscular training has been described as a multi-interventional programme that includes combinations of balance, core stability, strength, plyometric, agility and sport specific exercises (Coughlan and Caulifield 2007; Panics et. al 2008) and may be applied as a rehabilitation programme to restore neuromuscular control after joint injury or as a prehabilitation programme whereby the initiation of neuromuscular exercises after joint trauma may restore function and prevent degenerative changes later (Tenforde et. al. 2012). Various systematic reviews, including one Cochrane Database Systematic Review (de Vries et. al. 2011) have demonstrated the positive value of neuromuscular training in performance enhancement (Zech et. al. 2010), sports injury prevention (Hubscher et. al. 2010), injury prevention of lumbar region (Briggs et. al. 2013), lower limb injuries (Herman et. al. 2012), anterior cruciate ligaments (in female athletes) (Yoo et. al. 2010), and ankle instability (de Vries et. al. 2011; Lin et. al. 2012; O'Driscoll and Delahunt 2012) and ankle sprain prevention (Verhagen 2010).

The evidence is still limited by small sample sizes (Lin et. al. 2012), methodological flaws (Lin et. al. 2012), less than optimal measures used (O'Driscoll and Delahunt 2012), heterogeneity of population groups (Briggs et. al. 2013) and inconsistencies (Briggs et. al. 2013). Furthermore none of the studies were based on a dancing population. Despite these limitations, the application of an exercise programme that may not require equipment would be beneficial for a dance company that is required to tour both nationally and internationally. Furthermore an exercise programme that may be effective in reducing both non-contact and overuse injuries (Herman et. al. 2012), injury types noted in dance, provides a compelling case for its inclusion in an injury prevention strategy. Within dance, the ability to implement effective injury prevention is challenging. The "preseason" component of the season lasts only two weeks, in which preparation for the rigours of 6 hours of rehearsals a day on top of 1

½ hours dance class needs to be achieved. Providing strength gains through traditional strength training would be ineffective due to the restriction in time over which these gains can be made. Incorporating high load training used in traditional strength training during this period may also increase risk of concomitant injury. There is also the added challenge of preparing the dancer for the athletic requirements of the season without great hypertrophic muscle gains (noted with prolonged strength training) due to the aesthetic requirements of traditional classical ballet. Providing injury prevention within the working season has similar challenges including the extreme demands on dancers' available time for complementary conditioning. This is evident as the exposure time for dance related activities was far greater than that seen in other professional sporting disciplines in the first year of this study (Chapter 3). Therefore an intervention that incorporates low threshold training (to provide stability to local and global stability muscles), with a safe level of training that is evident in neuromuscular training would be seen as advantageous.

In Year 1 of this study, the injury prevention programme was undertaken without data from the injury audit programme. The injury audit provided insight that led to a number of changes in the comprehensive medical management programme employed. The higher incidence of ankle and lower limb injuries resulted in the need to explore balance/proprioception in more detail as part of the screening process. The increased incidence of lower limb and lumbopelvic injuries also influenced the need to develop an exercise intervention based on neuromuscular training due to the evidence of its efficacy in reducing lumbopelvic and lower limb injuries as well as enhancing performance (Zech et. al. 2010; Hubscher et. al. 2010; Briggs et. al. 2013; Herman et. al. 2012; Yoo et. al. 2010; de Vries et. al. 2011; Lin et. al. 2012; O'Driscoll and Delahunt 2012 and Verhagen 2010). Using an action research design as part of a qualitative research approach, changes to the screening and intervention programmes were made (Craig 2008, Meyer 2000, Waterman 2001, Malterud 2001). The aim of this chapter was to describe the changes to the comprehensive medical management employed at a professional ballet company as part of an in-house injury prevention strategy, incorporating changes to the screening and intervention programmes for the prevention and management of dance injury.

4.2 Method

4.2.1 Injury Surveillance

A yearly cohort of between 52 and 58 professional ballet dancers (Table 4.1), who were part of an international touring company were prospectively studied over three consecutive performance years (Year 1: 2005-2006; Year 2: 2006-2007; Year 3: 2007-2008).

Table 4.1: Participants by Age, Height, Weight and Year

	Gender (no.)	Age (yrs) [SD]	Height(cm)[SD]	Weight(kg)[SD]
Year 1	Male (n=25)	23 [4]	179 [4.3]	71.5 [4.7]
	Female (n=27)	25 [5]	162[3.9]	49.2 [4.04]
Year 2	Male (n=29)	24 [4]	179 [1.0]	71.5 [4.73]
	Female (n=29)	25 [5]	162 [0.96]	49.2 [4.05]
Year 3	Male (n=26)	24 [4]	179 [5.3]	72.2 [7.01]
	Female (n=27)	26 [5]	164 [3.6]	51.2 [5.59]

4.2.2 Functional Performance Screen

Alongside the prospective injury surveillance programme examining the incidence of injury of a cohort of between 52 and 58 professional ballet dancers who were part of an international touring company (Table 4.1), the in-house medical team employed the Functional Performance Screen (FPS) in the first two weeks of the beginning of Year 2 (2006-2007) and Year 3 (2007-2008), when the dancers had returned following a 5 week off-season break. The FPS is an in-house development of the Functional Movement Screen (FMS) that had been employed in Year 1 (2005-2006). The FMS uses 7 tests on a 4 point scale. The movements include the deep squat; the hurdle step; the in-line lunge; the shoulder mobility test; the active straight leg raise (ASLR); the trunk stability push-up; and the rotary stability test (Cook, Burton and Hogenboom 2006a,b). The FPS used in Year 2 and Year 3 had in addition to the 7 tests used in the FMS had a further two tests. Firstly an adapted Romberg test whereby the dancer would stand on one leg for 30seconds with the tested dancer having their eyes closed. The level of achievement was ranked by the examiner using the scoring system described for the FPS. The second test introduced was adapted from the Mens Test, based on a clinical test for determining instability of the sacro-iliac joint (Mens, Stam, Vleeming, et. al. 1995). The Mens test comprises of the patient lying supine and undertaking an active straight leg raise to 5cm. A positive test is recorded if the patient experiences any pain or describes a difference in strength or ability of one leg compared with the other (often described as one leg feeling "heavier" when lifted compared with the other leg). For the purpose of interpretation the pelvis was then manually stabilised, providing force closure for the sacro-iliac joint and the test is repeated to assess the impact of improving stability on the symptoms reported in the conducting of the test. The FPS used a 6 point scoring system; a score of 0 indicates "Pain/unable to perform"; 1 indicates "Very poor/achieves but with major compensation"; 2 indicates "Poor/achieves but with moderate compensation"; 3 indicates "Fair/achieves but with minor compensation"; 4 indicates "Good/achieves but with minimal compensation"; and 5 indicates "Excellent/achieves with no compensation" (Figure 4.3). The FPS scoring system was created as a means to extend two of the scoring categories in the FMS, namely 1 and 2 to allow greater differentiation for smaller/subtle changes but still allow scores to be assessed using either scoring system.

Figure 4.3: Scoring Criteria for the Functional Performance Screen and generalised Functional Movement Screen scores

<table>
<tr><th colspan="2">FPS</th><th colspan="2">FMS</th></tr>
<tr><td>0</td><td>Pain/
unable to perform</td><td>0</td><td>Pain/
unable to perform</td></tr>
<tr><td>1</td><td>Very poor/
achieves but with major compensation</td><td rowspan="2">1</td><td rowspan="2">Poor to very poor/ achieves with moderate to major compensation</td></tr>
<tr><td>2</td><td>Poor/
achieves but with moderate compensation</td></tr>
<tr><td>3</td><td>Fair/
achieves but with minor compensation</td><td rowspan="2">2</td><td rowspan="2">Fair to good/ achieves with minor to minimal compensation</td></tr>
<tr><td>4</td><td>Good/
achieves but with minimal compensation</td></tr>
<tr><td>5</td><td>Excellent/
achieves with no compensation</td><td>3</td><td>Excellent/
achieves with no compensation</td></tr>
</table>

4.2.3 Interventional Strategy

The intervention strategy was based on the information gained from the injury surveillance and FPS. An interpretation of the relationship of various movement patterns to intrinsic risk and injury was made through analysis of the results of the FPS as to where deficiencies may lie. This was done by comparison with the results of the individual and the group and in relation to both the FPS and the injury audit data. A Hybrid Interventional Model was then developed using the principles of neuromuscular training and used to design individual conditioning programmes. The model considers three key influencing factors: the injury (if there is an injury present) or deficit (as identified through the screening processes); the cause (of the injury or deficit); and the final objective or outcome being sought as a result of undertaking the programme. These are assessed to determine which the key "limiting factor" is. This is then used to influence the relative ratios of the three components of the conditioning programme, namely neuromuscular facilitation, isolated segmental deficit training and functional integration.

An example of a functional performance screening score sheet for an anonymised example patient is illustrated in Appendix 5. Data from the injury audit (Year 1: 05/06), indicated the example patient recorded two episodes of “Ankle instability or ligament sprain including sinus tarsi” resulting in 24 days and 2 days lost respectively. As a result an individualised conditioning programme was designed (Appendix 6).

4.2.4 Statistical Analysis

Multilevel modelling accounting for individual and repeated observations was employed to examine changes in screening scores for the FMS using the MLwin software (Version 2.22, Centre for Multilevel Modelling, University of Bristol, UK).

4.3 Results

The results of the FMS and extended FPS from Year 1, Year 2 and 3 are expressed as the mean and range of a potential score of 21 and 40 respectively (Table 4.2). In Year 1 dancers who scored 15 or lower averaged 8 injuries with an average severity of 6 days, while dancers who scored greater than 15 averaged 7 injuries and an average severity of 12 days. The group scoring above 15 did included two dancers with more severe injuries resulting in a prolonged period away from full dancing. In Year 2 those dancers who recorded an FPS score of 24 or below in the pre-season screen recorded a mean of 3 injuries with a mean severity of 4 days, while those who recorded a score greater than 24 sustained a mean of 4 injuries with a mean severity of 5 days. In Year 3 dancers who scored an FPS score of 24 or below recorded a mean of 4 injuries with a mean severity of 35 days (although this included one severe injury resulting in 310 days away from full dancing). Those dancers who recorded a score greater than 24 sustained a mean of 7 injuries and a mean severity of 4 days.

Table 4.2 Mean and Range of FMS and FPS Scores for Year 1, Year 2 and Year 3

	Functional Movement Screen (score out of 21)		**Functional Performance Screen (score out of 40)**	
Year	**Mean (%)**	**Range (%)**	**Mean (%)**	**Range (%)**
1	**15 (71)**	**11-19 (52-95)**	**n/a**	**n/a**
2	**13 (62)**	**9-17 (42-80)**	**24.7 (61.75)**	**17-32 (42-80)**
3	**13 (62)**	**10-16 (47-75)**	**24.2 (60)**	**18-30 (45-75)**

In respect to differences in FMS screening scores between Year 1 and Year 2 and 3, the MLWin software estimated

$$\text{scoreoutof21}_{ij} \sim \text{N}(XB, \Omega)$$

$$\text{scoreoutof21}_{ij} = \beta_{0ij}\text{cons} + -2.831(0.490)\text{years\_2}_j + -3.309(0.591)\text{years\_3}$$

$$\beta_{0ij} = 15.818(0.312) + u_{0j} + e_{0ij}$$

$$\left[u_{0j}\right] \sim \text{N}(0, \Omega_u) : \Omega_u = \left[4.276(0.634)\right]$$

$$\left[e_{0ij}\right] \sim \text{N}(0, \Omega_e) : \Omega_e = \left[0.000(0.000)\right]$$

$$-2^{*}loglikelihood(IGLS\ Deviance) = 390.474(91 \text{ of } 204 \text{ cases in use})$$

demonstrating a significant drop in mean FMS score from Year 1 to Year 2. No significant drop in score was evident in Year 2 to Year 3.

4.4 Discussion

4.4.1 Injury Prevention

The health benefits of exercise are well recognised. Similarly, it is recognised that an increase in physical activity with exercise can result in an increase in risk of injury. The findings of the Year 1 study (Chapter 3) indicated an overall injury incidence of 4.4/1000hrs to this cohort of dancers. Injuries to professional dancers can have a negative effect on their careers in the short term, which can include health and financial ramifications or even premature retirement from dance. There is also the potential negative impact on their long-term lifestyle, with evidence growing on the prolonged effects of injuries sustained during a professional career like the development of osteoarthritis (Tenforde et. al. 2012). These aspects justify the need to explore means to prevent injuries from occurring in order to reduce the impact of injury by those charged with the care of these performing athletes.

It has been indicated that action research as part of a qualitative research approach is particularly suited to identifying problems in clinical practice and helping develop potential solutions to improve practice (Meyer 2000). Action research is a period of inquiry that describes, interprets and explains social situations while executing a change intervention aimed at improvement and involvement (Waterman 2001). Action research has been identified as having three main components, namely: participatory character; democratic impulse; and simultaneous contribution to social science and change (Meyer 2000). As with the participation in action research, participants in this study were active in the change process between Year 1 and Year 2 and 3, particularly as work undertaken with the intervention programmes fell outside of the contract obligations of the dancers. As part of the democracy of action research, dancers were viewed as equal partners in this trial process and involved in the exercise development process and way in which complimentary exercise prescription are viewed and incorporated in a professional ballet company. The third component of action research relates to the theory-practice gap in clinical practice where practitioners, after identifying gaps in the traditional knowledge that cannot be explored through more accepted and more scientifically sound means like randomised control trials, draw on their intuition and experience to generate findings that are meaningful and useful to the environment that they are in (Meyer 2000). This is supported by Malterud (2001) who states the tacit knowledge of the experienced practitioner should be investigated, shared and contested, with qualitative research methods and strategies a means to contribute to a broader understanding of medical science. The screening and intervention aspect of this study represents such a situation. Due to the need to respond to information regarding risk to dancers through the first years injury audit data, along with the challenge of applying controlled studies in a high performance environment, changes to the nature of the comprehensive medical management programme were made using the lead researcher and clinicians intuition and experience. It was accepted that this will limit the level of evidence of the results.

This chapter looked to describe the changes to the comprehensive medical management employed at a professional ballet company as part of an in-house injury prevention strategy, incorporating changes to the screening and intervention programmes for the prevention and management of dance injury.

4.4.2 Screening

In Year 1 preseason screening took place using a normal movement screening programme, the FMS. With the additional insight gain through the evaluation of the injury audit data from Year 1, changes were made to the screening system (FPS). The FMS has been advocated for identifying gross risk factors for injury (Kiesel, Plinsky and Voight, 2007). After the first year of the study it was felt there was a need to enhance the understanding of the interaction between balance and the proximal stability created by the sacro-iliac joint as well. Therefore in addition to the original 7 test based FMS, two further tests were included, namely the modified Romberg for balance and the Mens Test for sacro-iliac joint instability. The results of Year 1 indicated that a high incidence of injuries originated from the ankle region, with a high proportion of those due to ankle instability. This was further supported by the results of other dance studies in the literature (Gamboa et. al. 2008, Mcaintyre and Joy, 2000, Milan 1994, Nilsson et. al. 2001, Prisk, et. al 2008, Solomon et. al. 1999, Wiesler, et. al. 1996). It was also felt that the role of ankle stability influenced potential injuries further up the kinetic chain. There has been some support for validity and reliability of the single leg balance test in predicting ankle sprains

(Trojian and McKeag 2006). The second test, the Mens test for instability of the sacroiliac joint, was also taken into consideration with the results of the balance test (as well as the other FPS tests). The sacro-iliac joint provides a key link in the overall kinetic chain between the lower limb and hip, and the trunk. While the stabilisation of the sacroiliac joint is dependent on two interdependent factors namely the interlocking ridges and grooves as part of the articular surface or form closure, and the compressive force closure due to the involvement of muscles, ligaments and fascia (Pool-Goudzwaard, Vleeming, Stoeckart, et. al. 1998), it was the influence of the second factor that was of most interest in regards to the information required for the design of individual conditioning programmes. If these are weak or insufficient they affect sacroiliac stability (Pool-Goudzwaard et. al. 1998) and load transfer through the pelvic girdle (Beales, O'Sullivan, Peter et. al. 2009a,b; Mens, et. al. 1995). It was felt that this was a fundamental component where instability and resultant dysfunction originates, and its inclusion as a specific test within the whole Functional Performance Screen allowed an improvement in the design of interventional programmes through greater specificity of the intrinsic risk factors. If the dancer scored poorly in the single leg balance test for example, but had a negative Mens test, a proprioception based conditioning programme may have been considered. If the dancer scored low on a balance test, as well as having a positive test for instability of the sacroiliac joint, a proximal stability programme would have been considered prior to a traditional proprioception based programme. It was hypothesised that the source of the apparent poor balance was the lack of a stable proximal source. The ability to identify the body region from which the instability originated from as opposed to applying a standard lower limb proprioception programme allowed a far greater degree of specificity to be added to the individual conditioning programmes.

The design and implementation of the FPS was based on the need to capture data that would be used in the development of individualised conditioning programmes as part of an injury prevention strategy. A further avenue in reducing the impact of injuries may come from tackling the recurrent and chronic nature of symptoms, which has been linked with the dysfunctional movement control (Dankaerts, O'Sullivan, Burnett, et al 2006; Hodges and Moseley 2003; Hungerford, Gilleard and Hodges 2003, O'Sulivan 2005). The use of a screening system that incorporates motor patterns within fundamental movement testing allowed these factors to be appreciated. Within the original FMS, the presence of asymmetries plays a key role in the interpretation of results. Likewise with the FPS it is important to determine if deficiencies noted are asymmetrical? If so, is it the product of the specificity of the sport/dance in question, or is it in response to how the body has accepted the loading and training that the subject has undertaken. The interpretation of the results also has to be taken not as an exponent of, for example muscle power or length, noted in some musculoskeletal screening systems (Bradley and Portas 2007), but as part of a summation of the ability of the "kinetic chain" to accept and cope with the loading during athletic performance. This concept has been reflected on in the literature, notably with the role of diminished hamstring length and low back pain (Halbertsma, Göeken, Hoff, et. al. 2001). A question can be raised as to whether the diminished hamstring length increases the loading on the lumbar spine through its influence via the pelvic cage, or whether the failure of the lumbar spine to accept the daily activity/sport loading results in compensatory changes of global muscles, like the hamstring muscle group, giving the appearance of diminished length. By using the information gained via the movement patterns though the FPS, these issues can be better appreciated. Part of this process is achieved through understanding changes to motor firing patterns in muscles, particularly as they have been shown to be dysfunctional in the presence of back pain (Hodges and Richardson, 1996). The alteration of muscle function properties due to concurrent pathology appears to be supported by Marshall, Mannion, and Murphy (2010) who indicate that there is no concentric or eccentric power loss in patients with low back pain, but did find alterations within the balance of concentric/eccentric muscle activation, indicating that this is a product of a behaviour based response as fear avoidance rather than of physical origin. This may therefore explain Herbert and Gabriel's (2002) findings that interventions like muscle stretching may not always be an effective way of reducing injury, as stretching does not account for the reasons why the muscle compensated in a response to overloading. Diminished muscle length can be seen as a symptom rather than a cause (Russell, 1991). By removing the symptom, patients tend to feel better, and may occasionally get better. But the risk is that if the underlying reason for the symptom is not addressed, the symptoms will return. Therefore the implementation of an intervention programme using the FPS, the rationale for addressing deficiencies can be based on an approach that respects the regional interdependence of loading in the body and provides the basis for a solution for the cause of the symptoms encountered. A notable aspect of the Functional Performance Screen in relation to other dance screening in the literature (Liederbach, 1997; Siev-Ner, et. al. 1997) is the absence of any dance specific testing. The anticipation was that due to the high level of skill dancers' exhibit, undertaking a skill-based assessment using dance specific tests would fail to provide an adequate means to determine the deficiencies of movement patterns. A decision was also made based on observations in the first year's FMS screening to allow for a greater differentiation in the scoring system to assist in the design of conditioning programmes to match the specificity of the dancer's needs, where small changes/alterations impact on movement quality with dancers. As such an expanded 6 point scoring system was employed which allowed smaller changes in movement patterns that may have great implications to risk of injury to be accounted for.

The results of the FMS undertaken prior to the commencement of Year 1 indicated an overall average score of 15 (out of 21). This is below the failure threshold of 16 determined by Peate et al. (2007) for fire-fighters, but greater than 14 determined by Kiesel et. al. (2007) for increased risk of serious injury in American Football players. To date, there have been no published reports as to the use of and subsequently the potential predicative value of using the FMS in dance. The dancers who scored 15 or lower averaged 8 injuries with an average severity of 6 days, while dancers who scored greater than 15 averaged 7 injuries and an average severity of 11 days. The group scoring above 15 did included two dancers with more severe injuries resulting in a prolonged period away from full dancing. When comparing the means of FMS scores between Year 1 and Year 2, a significant decrease in score is reported. A further non-significant decrease in score is noted between Year 2 and Year 3. It might have been anticipated that an improvement in scores would have been reported with the employment of an exercise programme as part of the intervention. The potential reason hypothesised for a lack of improvement in screening scores is based on evidence of decay and detraining noted with periods of cessation of training. In a review of skill decay and skill retention, Arther, Bennet, Stanush, et. al. (1998) indicates that "artificial tasks" including gymnastic skills like balancing were more prone to decay. The impact of detraining on decay of physiological and functional variables has also been demonstrated in other sport, where following a 5 week period of complete cessation from training a significant reduction was noted (Garcia-Pallares, Carrasco, Diaz, et. al. 2009). The dancers in the current study were subject to a 5-week complete cessation from training (as part of the scheduled summer holiday) between the end of Year 2 and the beginning of Year 3, where the FPS was repeated. The failure of the scores in the FPS testing to improve at the beginning of each season may be explained by the decay and detraining noted with a 5 week period of complete cessation of training. Further research needs to explore this aspect by incorporating retesting of the FPS during and at the end of each season. This was not feasible due to time restraints on a professional working ballet company and its medical team. A further reason for the decrease in the scores is also attributed to the increased awareness of the tester to the relevance of certain compensatory patterns to injury presentations observed through the injury audit data. This resulted in the down rating of scores in particular "a risk" areas. This strengthens the need for future research in establishing the implementation of this screening in dance as well as the inter and intra-tester reliability of the screening in dance.

The International Olympic Committee consensus statement on periodic health evaluation (PHE) indicated the evidence for musculoskeletal PHE is limited (Ljungqvist, et. al. 2009), supported by the results of the evidence base of pre-participation evaluations by Wingfield, Matheson and Meeuwisse (2004). Statistical analysis of the screening data in isolation failed to support its use as a predictor of injury. The nature of the interventional strategy employed required the combination of the results of the screening system with that of the injury audit to determine the composition of individualised conditioning programmes. As such, while a comparison can be made between screening scores of the various years, its value is determined by its ability to steer the design of conditioning programmes rather than mean group scores.

4.4.3 Intervention

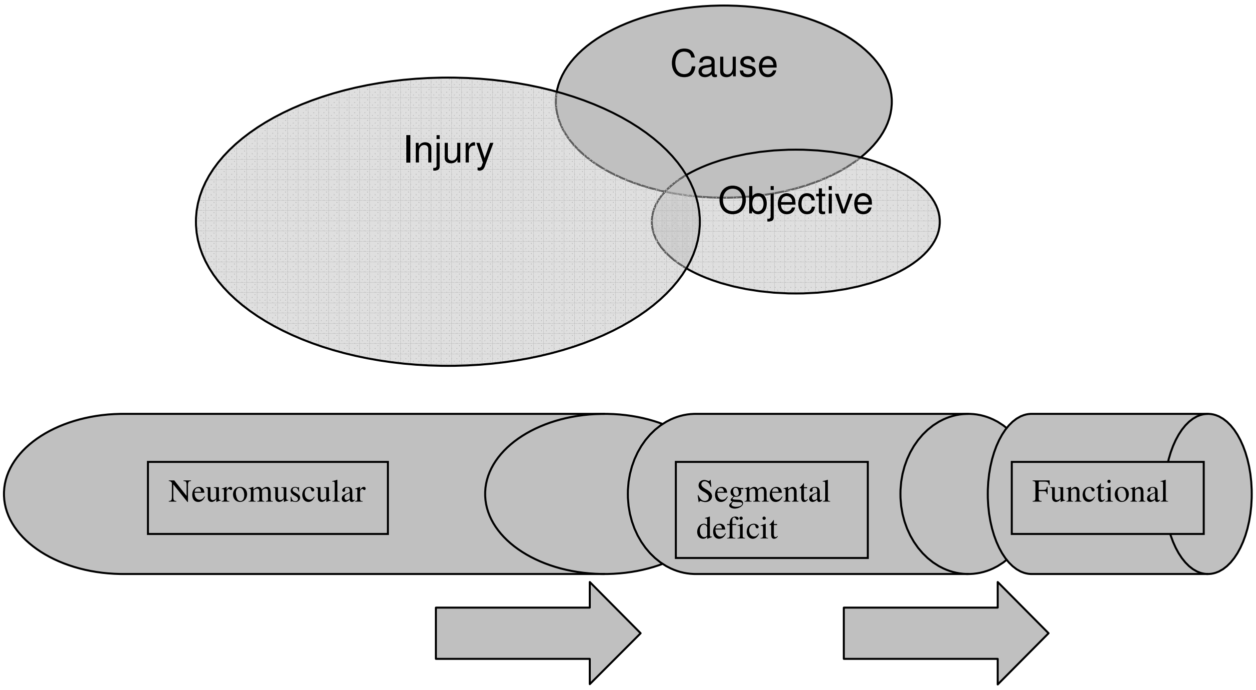
In Year 1 the intervention programme took the form of individual exercise programmes designed using screening outcomes from the FMS. With the addition of injury data the greater understanding of injury profiles, including understanding mechanisms of injury or inciting events, allowed a greater degree of specificity to be applied to exercise programmes.

The nature of the intervention for this cohort of dancers needed to conform to three main factors. The primary factor was functional outcomes, meaning the intervention, although not dance specific, needed to reduce injuries within dance related activities. Secondly, the intervention needed to achieve this outcome within the time retrains imposed on the dancer within their preseason and in-season scheduling, where time allocation for complementary training is extremely limited. Finally, the intervention needed to respect the aesthetic requirements of dancers, where changes in body shape through hypertrophic change due to strength training could be considered unacceptable. The decision to use a neuromuscular training based intervention programme was based on a belief that it would enable the functional outcomes required to be achieved. A number of systematic reviews have demonstrated the benefits of neuromuscular training in performance enhancement and injury prevention including (Zech et. al. 2010; Hubscher et. al. 2010; Briggs et. al. 2013; Herman et. al. 2012; Yoo et. al. 2010; de Vries et. al. 2011; Lin et. al. 2012; O'Driscoll and Delahunt 2012 and Verhagen 2010). Research has suggested that both strength and fitness levels in dancers are poor in comparison to other elite level sports participants (Brinson and Dick, 1996; Koutedakis, Agrawal, and Sharp, 1999; Koutedakis and Jamurtas, 2004; Koutedakis, Stavropoulos-Kalinoglou, and Metsios, 2005). Yet the performance output of these dancers suggests another means to provide the ability to perform such athletic feats over the vast number of shows per year. Although questions may be raised over the validity of some traditional strength and fitness based tests for dance, one suggestion as to the performance outputs in dance in the absence of higher levels of strength or fitness has been due the high level of skill observed in dancers (Allen and Wyon 2008). This level of skill may allow athletic movements to be performed with the greatest degree of efficiency, thereby reducing the need for higher levels of strength or fitness. A major component of the neuromuscular training approach is the activation of correct muscles. This is to provide the stabilising of joints which reduces the need for compensatory and/or over-activation of other muscle groups. This over/incorrect activation of muscle groups for the purpose of providing joint stability leads to poor efficiency of energy and harnessing of muscle power. As the dancers were perceived as naturally using this principal of enhanced efficiency, implementing a training programme that would complement their natural training was postulated to have the highest opportunity to achieve the required outcome. It was felt that the role of correct motor control function, allowing the high level of skill, was critical to the normal resilience of dancers to injury. As such an intervention where support for the use of low threshold training like motor control stability/neuromuscular control in the correction of motor control dysfunction had been demonstrated (Hides, et. al. 2001; Jull et al., 2002; O'Sullivan, 2000) would enable the primary objective of improved functional outcome of reduced dance related injuries to be achieved.

A component of motor control stability/neuromuscular control arises from the role of afferent nerves. Mandelbaum et al. (2005) indicated that the afferent signals have two distinctive roles, namely feedback and feed-forward mechanisms, where feed-forward mechanisms are a result of a pre-activated preparatory activation of muscle (Mandelbaum et.al. 2005) as opposed to the slower more reflexive feedback mechanism elicited through the afferent input of force to joint. The feed-forward aspect of neuromuscular control is a key component that can be utilised for injury prevention strategies. It was felt that the preparatory aspect of feed-forward neuromuscular control would allow changes in resilience to injury to be achieved in a shorter time period than the achievement of adaptive muscle changes needed with strength based exercise intervention approach. It would also eliminate the potential of unwanted hypertrophic muscle changes that could adversely affect the aesthetic requirements of the individual dancers. By using a motor control stability/neuromuscular control approach to the intervention strategy it was felt that the correct sequencing of exercise types would be achieved. In this process the establishment of local and global stabilisation prior to the engagement of any higher threshold intervention would not only allow a more effective gain to be made from the progression of exercises due to the creation of a suitable "platform" from which functional and higher threshold exercises could be based, but also by reducing the risk of concomitant injury due to a failure of establishing local or global stability while applying a higher threshold loading of the body.

The development of conditioning programmes for each individual was based on a "Hybrid Intervention Model". The unique model was developed through observations of key performance attributes from elite sport and elite dance and based on the principals of neuromuscular training. It was important that the same model could be applied to the design of conditioning programmes for dancers with an injury as well as dancers for whom an injury risk was identified. The model incorporated the skill and efficiency of movement observed in elite dance with the strength and fitness observed within elite sports participants. The hybrid looks to combine movement efficiency with strength training within the conditioning programme. Another feature of the hybrid model is that it uses three points of consideration for each programme. These are the Injury (if there is an injury present) or deficit (as identified through the audit and screening processes), the Cause (of the injury or deficit) and the Final Objective or outcome being sought as a result of undertaking the programme. All three factors will influence the construction of an intervention programme and need to be part of the overall programme constructions consideration, but the model looks to identify which of the three is the key “limiting factor” for the current stage (for example acute/early stage, sub-acute/mid stage, or chronic/late stage) of the injury/deficit. This then influences the relative ratios of the three stages that are combined to form each conditioning programme/session, namely neuromuscular facilitation, isolated segmental deficit training and functional integration. In the early stage of an injury or an identified deficit, the key limiting factor may be the injury or the deficit itself, with the cause and end stage objective carrying less importance or weighting. The resulting programme then focuses on neuromuscular facilitation as its largest component, with smaller components addressing the segmental deficit and functional integration (Figure 4.4).

Figure 4.4: Early Stage Conditioning Programme



The development of correct neuromuscular control and movement efficiency patterns are required provide a safe foundation to load an injured or deficient region without risk of injury or compensatory movement or muscular patterns. The segmental deficit component identifies the muscle group/s within the movement chain that is influential to the overall functioning but is deficient, and looks to improve its isolated function. It is hypothesized that in the presence of a segmental deficit, movement can be achieved with similar functional outcomes but with degrees of compensatory movements that may entail potential risk of injury or diminished performance. The last component of the conditioning programme incorporates "functional integration". This component uses the establishment of improved neuromuscular firing patterns and isolated strengthening and immediately challenges these in functional positions. In the early stages these may be in unloaded postures that mimic or replicate functional activities like running or jumping. As the individual progresses through the training periods the shift in the limiting factors are reflected in the construction of the conditioning programme. In the mid stage of the training period, the limiting factor may no longer be the injury/deficit, and so the emphasis may shift towards the cause. Here the changes within the conditioning programme will see a slightly smaller component of the programme addressing the neuromuscular firing patterns, but a greater emphasis on any segmental deficit, along with a slightly greater shift towards functional integration. At end stage, the injury/deficit as well as the cause should be less influential and the main limiting actor would come from the proposed outcome or objective, like returning to full performance on stage for a dancer. Here the conditioning programme sees a smaller emphasis coming on the neuromuscular and segmental deficit components of the programme and a larger emphasis on the functional integration. Despite the shift towards the functional integration, the programme design still allows for on-going work within the neuromuscular and segmental deficit aspects. This is done to ensure the on-going efficiency of the movement patterns alongside the strength and function work. It is this hybrid approach that is considered key to improving performance outcomes and reducing (re)injury risk. Notable throughout the conditioning programme but emphasised in the third phase was the need to perform exercises with efficiency and no compensatory movements. The progression through the programme was dependent on changes/improvements to the pre-test determinant. The results of the Men's test and the role of the sacroiliac joint were fundamental. The presence of a positive Mens test would normally form the foundation for the first phase and the development of the motor control/firing patterns of the muscles that provide stability to the sacroiliac joint. Gluteus Maximus and Piriformis muscles have been advocated as playing a key role in improving force closure of the sacroiliac joint and subsequent improvement in stability (Snijders, Vleeming, and Stoeckart 1993). Up to three key exercises (see exercises 1,2,3 in conditioning programme example- Appendix 6) were used to facilitate this action. In order for progression to the next exercises, dancers were instructed to repeat the Mens test and only to proceed if the Mens test had improved. The exercises in the segmental deficit portion of the programme would then looked to add elements of support for the muscle groups needed to maintain sacroiliac joint stability as well as address the concurrent deficiencies noted in the screening and audit data, while the final portion of the programme would look to challenge those key areas in a functional biomechanical posture.

4.4.4 Interpretation of Results

The value of van Mechelen's model is that it provides a combined approach to understanding (and reducing) risk through the establishment of the extent of the injury along with potential intrinsic risk factors. It is through this combined body of knowledge that effective interventions can be planned (and tested) as opposed to relying solely on a pre-participation screening. With the absence of a control group to test the efficacy of the individual neuromuscular training programmes alongside a failure to observe changes in screening scores, the original van Mechelen model indicates the use of re-auditing injury data to fully appreciate the impact of interventional studies

4.5 Summary

The information gained from the first year of the injury surveillance (chapter 3) indicated that a relatively high incidence of injury exists within this cohort of dancers compared with other injury incidence studies in ballet. As a result, the in-house medical team felt that a shift in emphasis was needed in order to address this. This entailed a move from a treatment focussed bias to an injury prevention focus based on improving intrinsically indicated risk factors. This was underpinned by the information gained from the pre-season screening using the principles of movement patterns and asymmetries. Despite not using dance specific testing as part of the FPS, the results of this system provided valuable information for the medical team as to the asymmetries and deficiencies of movement patterns among this cohort of dancers. The inclusion of balance and sacroiliac joint instability tests along with an expanded scoring system provided a greater foundation with increased understanding to the source of the intrinsic risks noted in dance.

An intervention based on the exercise principals of neuromuscular training using the Hybrid Intervention Model was chosen. The decision was based on an assumption that a key to the dancer's resilience to injury was borne out of their high level of skill and efficiency of movement over the comparable levels of fitness and strength noted in other elite level sports participants, and that the potential reason for injury was due to motor pattern dysfunction. It was also decided that risk of concomitant injury was a potential if a high threshold training strategy was implemented prior to the achievement of local and global stabilisation through low threshold training in motor control stability/neuromuscular control. Other factors influencing the decision to utilise this approach was the restricted time allowed within dancers schedules whereby a more comprehensive strength based programmes would not have sufficient time for adaptive changes to be achieved. It was also decided the potential of hypertrophic changes was greater with more traditional strength based intervention programmes, something that had been indicated to be an undesired affect within classical ballet.

4.6 Conclusion

In comparing the results of screening scores between Year 1, Year 2 and 3, no improvement in mean scores was noted. This is may be explained due to the decay of any training effect as a result of the interventional strategy (individualised training programmes) as a result of a 5 week cessation of training period prior to the retesting of the FPS screening programme alongside a down rating of certain areas in light of their link to observed injury patterns in the injury audit. Future research needs to repeat the FPS before and after intervention programmes to better determine its efficacy and suitability in dancers as well as establish the inter and intra tester reliability for this population group.

Chapter 5: Observational changes in injury incidence and severity following the changes to the comprehensive medical management programme in a professional ballet company: a 3 Year Prospective Study

Data from this chapter has been published in Allen, N; Nevill, A; Brooks, J; Koutedakis, Y; Wyon, M (2013) The Effect of a Comprehensive Injury Audit Programme on Injury Incidence in Ballet: A 3-Year Prospective Study Clin J Sport Med. 2013 Sep;23(5):373-8. doi: 10.1097/JSM.0b013e3182887f32.

5.1 Introduction

Sport participation can entail a risk of injury (Kujala, Taimela, Antti-Poika et. al., 1995; Parkkari, Kujala, and Kannus, 2001; van Mechelen, Hlobil, and Kemper, 1992). Part of the responsibility of those charged with caring for sports persons is to mitigate that risk. Artistic athletes like dancers (Hamilton, Hamilton, Marshall et al. 1992), are exposed to extreme physical demands (Twitchett, Angioi, Koutedakis, et al. 2009) and are also subject to risk of injury (Solomon, Solomon, Micheli, et al. 1999, Hincapie, Morton, and Cassidy 2008) with injury rates varying from 0.62-5.6 injuries/1000hrs (Gamboa, Roberts, Maring et al. 2008, Luke, Kinney, D'Hemecourt, et al 2002, Nilsson, Leanderson, Wykman, et al 2001).

Injury has been reported to be multi-factorial (Bahr and Holme 2003, Meeuwisse 1994 Meeuwisse, Tyreman, Hagel, et. al. 2007) and so strategies to prevent injuries may also need to be multi-factorial. Understanding injury risk, through establishing the extent of the injury, along with potential intrinsic risk factors, are key elements from which interventions can be planned and tested. The use of injury history and pre-participation screening data regarding musculoskeletal risk factors has been suggested in sports medicine (Fuller, Ojelade, Taylor 2007).

In dance medicine literature, however, there are just a few epidemiological and screening studies from which interventional strategies for injury prevention can be evaluated. Bronner, et al. (2003) set out to determine the effect of implementing on-site medical care on in a modern dance company. The results revealed a significant reduction in workers compensation cases in the following three years. Similarly the positive impact of moving from an insurance-based funded system to an "in-house" medical care system for a professional ballet company has been reported over a period of 5 years (Solomon, Solomon, Micheli, et al. 1999). Both studies have demonstrated the impact on injury incidence with the implementation of in-house medical care. Nevertheless, it is still unknown the impact of combining injury audit data with screening data in the construction of conditioning plans on injury incidence in a ballet company that already has comprehensive in-house medical provision.

Recognising the detrimental impact and implications of injury on dancers (described in Chapter 1), and the incidence of injury reported in dancers (reported in Chapter 2 and 3), the aim of this study was to reduce injury in this cohort of professional ballet dancers. The expected impact of which was a reduction of injuries (both overuse and traumatic) and a reduction in the total amount of time lost to injury. The objective of this study was to observe injury incidence and severity in this cohort of professional ballet dancers over a three year period. In particular to observe differences that may have occurred due to alterations to the comprehensive medical management programme employed, notably screening and intervention programmes in addition to detailed injury surveillance data. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for reporting of observational studies (von Elm et. al. 2008) was used to guide the construction of the study.

5.2 Method

5.2.1 STROBE

The methodology of choice for interventional studies is randomised control trials (RCTs). It is however recognised that even RCTs can be subject to bias if they lack methodological rigor (Juni, Altman, Egger 2001). The response to the need for adequate reporting of findings, led to the development of the Consolidated Standards of Reporting (CONSORT) statements (Schulz, Altman, Moher 2010). It is appreciated that much of biomedical research is observational. (von Elm et. al. 2008). It is also noted that inadequate reporting of such research limits its value. Following on from the CONSORT initiative and the improvements noted in the quality of reports in randomised trials, a similar initiative was established to develop recommendations for the reporting of observational studies: the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement (von Elm et. al. 2008). The STROBE Statement checklist of 22 items was used to guide the construction and presentation of the study where relevant.

5.2.2 Injury Surveillance

A cohort of professional ballet dancers (Female: Table 5.1; Male: Table 5.2), who constituted an international touring company were prospectively studied over three consecutive years. The main methods for this study have been documented in detail in chapter 3. A time-loss definition of injury was used whereby "any injury that prevented a dancer from taking a full part in all dance related activities that would normally be required of them for a period equal to or greater than 24 hours after the injury was sustained”. In order to differentiate between full withdrawal from dance related activities and partial withdrawal from dance related activities a second injury definition was included, whereby if an injury resulted in the full withdrawal from any dance related activities (class, rehearsal and performance), the number of days that no dance related activity took place was recorded as “full absence from dance related activity” as a component of the overall severity in days until full participation in dance related activities took place. Injuries were reported by one of 3 full-time in-house physiotherapists on a standardised injury reporting form. No changes to the medical team were experienced throughout the study period. No further changes to the methodology described in chapter 3 were undertaken. All research data was collected in accordance with the University of Wolverhampton’s School of Sport, Performing Arts and Leisure Ethics committee (Appendix 1 and 3).

Table 5.1: Female Participant’s Age by Rank and Year

	Year 1		**Year 2**		**Year 3**	
Rank	(n=)	Mean Age (SD)	(n=)	Mean Age (SD)	(n=)	Mean Age (SD)
Principal	4	28(3.8)	3	30(4.0)	3	31(4.0)
Soloist	7	29(4.3)	8	29(5.3)	9	29(4.9)
1st Artist	5	23(2.1)	6	23(2.0)	4	25(2.6)
Artist	11	21(2.6)	12	22(3.0)	11	22(3.4)

Table 5.2: Male Participant's Age by Rank and Year

	Year 1		Year 2		Year 3	
Rank	(n=)	Mean Age (SD)	(n=)	Mean Age (SD)	(n=)	Mean Age (SD)
Principal	4	28(0)	4	29(2.6)	3	30(3.1)
Soloist	4	27(3.8)	5	27(3.8)	5	25(5.0)
1^{st} Artist	5	24(3.6)	7	24(4.0)	5	27(2.6)
Artist	12	20(1.7)	13	21(1.8)	13	21(1.7)

5.2.3 Functional Performance Screen

In addition to the injury surveillance, a screening programme was undertaken in the first two weeks of the beginning of Year 2 (2006-2007) and Year 3 (2007-2008). This was after the dancers had returned from a 5 week off-season break and had an initial build up phase of their return to dance. This constituted an incremental progression in intensity in class. The full detail, justification, and evidence for the screening programme is described in the chapter 4. This includes the difference between the screening programme used prior to Year 1 of the study and Year 2 and 3, being the expansion of the Functional Movement Screen (FMS) (Cook et. al. 2006a, Cook et. al. 2006b) through the inclusion of a single leg balance test and the Mens Test, alongside an expanded 6 point scoring system from the traditional 4 point scoring system described in the FMS (Kiesel et. al. 2007).

5.2.4 Interventional Strategy

The interventional strategy employed was the alteration to the comprehensive medical management programme. This included the design and implementation of individual dancer conditioning programmes, using the Hybrid Intervention Model with information gained from the injury surveillance and screening systems. The individualised exercise programmes followed a three stage approach and was based on the principles of motor stability control (Mottram and Comerford 2008) and neuromuscular control (Mandelbaum, Silvers, Watanabe, et. al. 2005).

5.2.5 Statistics

The severity of injuries was calculated as the number of days between the date of injury and date of return and reported as mean severity with 95% confidence intervals (CIs).

The incidence of injury was calculated as the number of injuries per 1,000 hours of dancing with 95% confidence intervals. A Poisson distribution model was used to calculate CIs. The injury count was analysed assuming a Poisson distribution using the MLwin software (Version 2.22, Centre for Multilevel Modelling, University of Bristol, UK).

Equation 1: Poisson Distribution Model

$$Injuries_i \sim Poisson(\pi_i)$$

Because injury frequencies are counts, the numbers of injuries were analysed using a log link. For the current injury data, we assessed the effect of years on the number of injuries using the following model where cons is the constant intercept parameter (for year 1) and β_2 and β_3 is the estimated difference due to years 2 and 3 respectively.

Equation 2: Log-linear Poisson regression model

$\text{Log}(\pi_i)=\text{cons} + \beta_2*\text{year2} + \beta_3*\text{year3}$,

In respect to injury count the MLwin software estimated:

Equation 3: Log-linear Poisson regression model detail

$$log(\pi_i) = 1.854(0.052)cons + -0.675(0.089)year2_i + -0.832(0.094)year3_i$$

$$var(injuries_i|\pi_i) = \pi_i$$

By taking antilogs, as a Poisson distribution cannot have a negative injury count, the estimated mean injuries per dancer for years 1, 2 and 3 were:

year 1 = exp (1.854) =6.39
year 2 = exp (1.854-0.675=1.179) =3.25
year 3 = exp (1.854-0.832=1.022) =2.78

5.3 Results

5.3.1 Injury Surveillance

In Year 1 (2005-2006) 355 injuries (female 172; male 183) were reported, with 183 injuries in Year 2 (female 76; male 107) and 174 injuries in Year 3 (female 75; male 99). Overall exposure periods were greater in Year 2 (89146 hours) and 3 (86072) compared with Year 1 (79924). In relation to gender, female dancers' exposure was 41499 hours in Year 1, which increased in Year 2 (44573 hours) and reduced again in Year 3 (41499 hours). Exposure periods increased for male dancers between Year 1 (38425 hours) to Year 2 (44573 hours) and Year 3 (44573). The decline in year 2 was found to be -0.675 (SE=0.089: P<.001) and the decline by year 3 was also significant - .832 (SE=0.094; P<.001).

From observing the parameter estimates and the SE for years 2 and 3, the decline in the mean number of injuries per dancer in years 2 and 3 are highly significant (both more than 7 times their SE). The overall incidence of injury dropped from 4.44 injuries per 1,000 hours (4.00-4.93) (CI) to 2.05/1000hrs (1.78-2.37) in Year 2 and 2.02/1000hrs (1.74-2.35) in Year 3. This drop in injury incidence from Year 1 was seen for both female and male dancers. The incidence of injury was lower for females compared with males throughout the 3 years of the study (Figure 5.1).

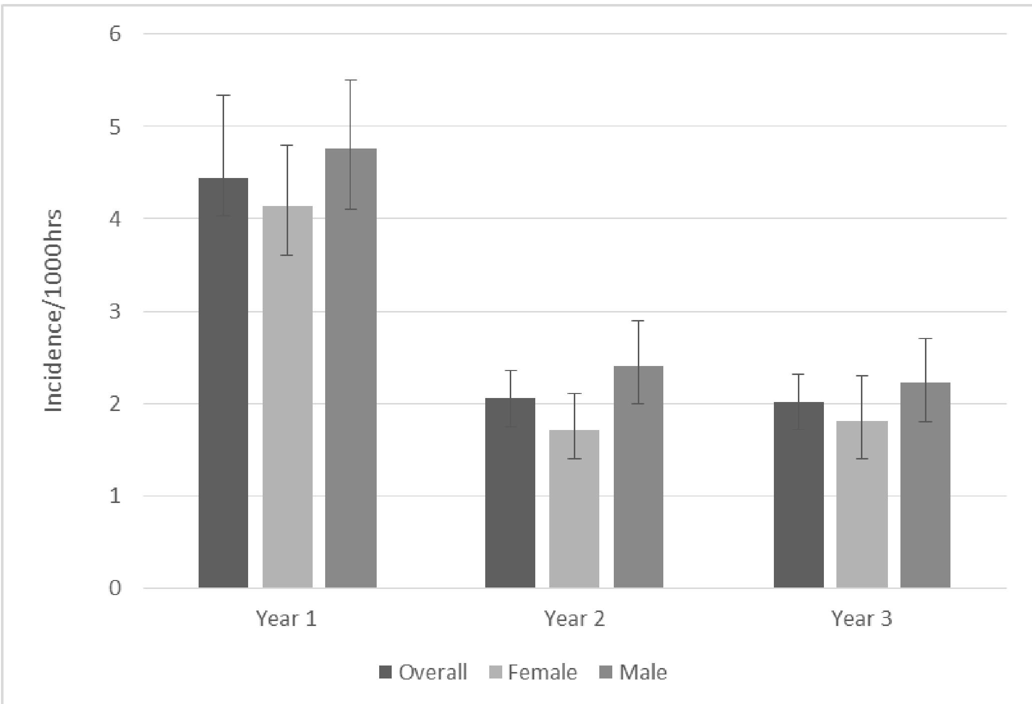


Fig 5.1: Injury Incidence for Year 1, 2 and 3

The mean severity in Year 1 of the study was 7 days (female: 4 days; male: 9 days) with a risk (as a product of incidence and severity) of 30 days/1000hrs (female: 17 days/1000hrs; male: 45 days/1000hrs). In Year 2 the mean severity increased slightly to 9 days, with an increase in the mean severity for both female and male dancer injuries (female: 5 days; male: 11 days) and risk of 18 days/1000hrs (female: 9 days/1000hrs; male: 27 days/1000hrs). In comparison to Year 1 and Year 2, Year 3 recorded a further increase with mean severity 11 days. (Figure 5.2)

The mean severity of male injuries decreased, but a greater difference in mean severity of female dancers was noted (male: 8 days; female: 15 days) and risk at 23 days/1000hrs (male: 19 days/1000hrs; female: 27 days/1000hrs). In Year 3 of the study, one female dancer sustained a severe injury resulting in 310 days where dance performance was affected (Figure 5.3). There was an overall reduction in days lost between Year 1 (2413 days lost) to Year 2 (1608) and Year 3 (1965) (Fig 5.4).

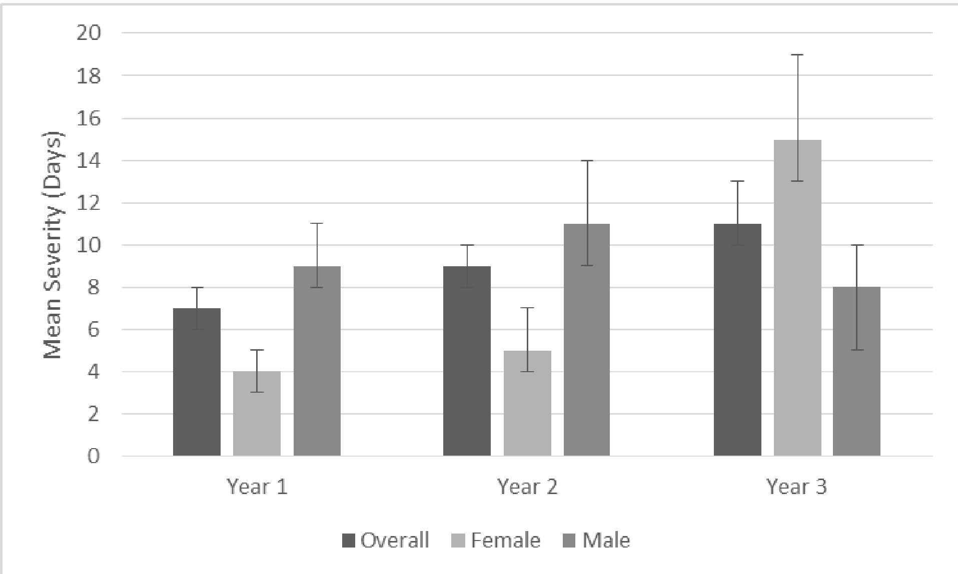


Figure 5.2: Injury severity for Year 1, 2 and 3

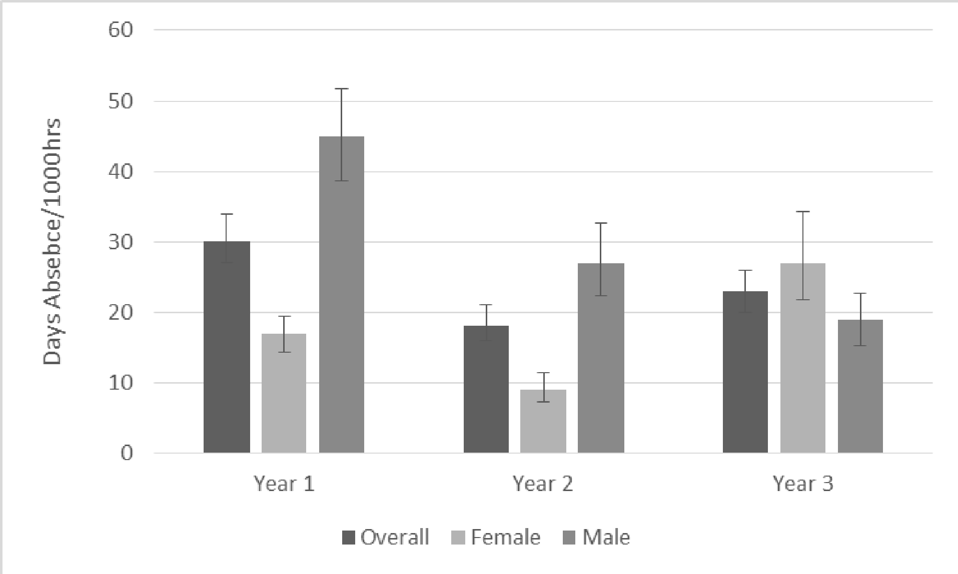


Figure 5.3: Injury risk for Year 1, 2 and 3

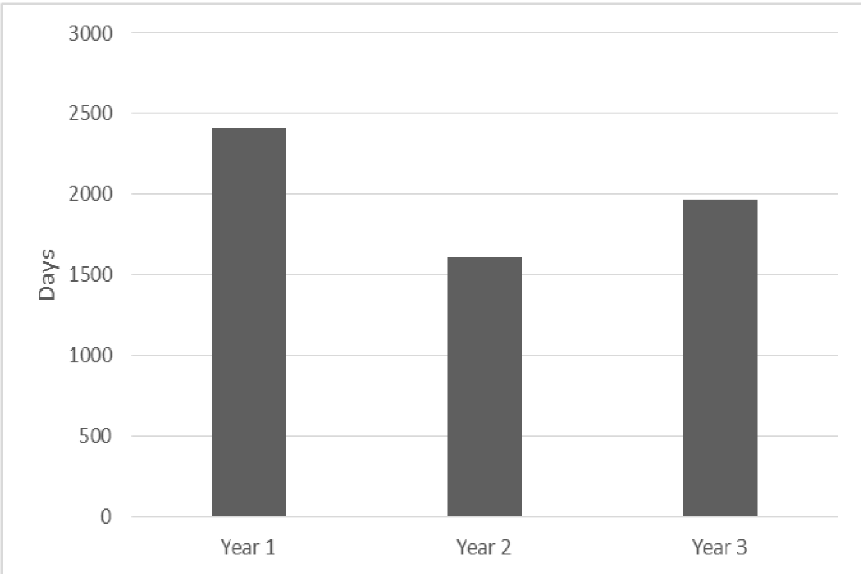


Figure 5.4: Overall days lost Year 1, 2 and 3

The number of injuries that included a period of time where full withdrawal from any dance related activity in female dancers reduced between Year 1 (22) and Year 2 (20) and 3 (16), however, this also represented an increase in the percentage of injuries in Year 2 (20%) and Year 3 (21%) compared with Year 1 (13%) (Table 5.3). Similarly, the number of injuries that included a period of time where full withdrawal from any dance related activity for male dancers reduced between Year 1 (36) and Year 2 (34) and 3 (25), conversely, this represented an increase in the percentage of injuries in Year 2 (32%) and Year 3 (25%) compared with Year 1 (20%) (Table 5.4).

Table 5.3: Injury Incidence for Female Dancers by Year and Time Loss (partial or full withdrawal)

	Year 1				**Year 2**				**Year 3**			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI))	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI))
Partial withdrawal	150 (87)	3.61 (3.1-4.2)	4 (3.07-4.22)	13 (11.09-15.27)	61 (80)	1.37 (1.1-1.8)	5 (3.84-6.34)	7 (5.25-8.68)	59 (79)	1.42 (1.1-1.8)	11 (8.43-14.04)	16 (11.99)
Full withdrawal	22 (13)	0.53 (0.35-0.81)	7 (4.64-(10.70)	4 (2.46-5.67)	15 (20)	0.34 (0.20-0.56)	7 (4.18-11.50)	2 (1.41-3.87)	16 (21)	0.39 (0.24-0.63)	31 (18.84-50.19)	12 (7.26-19.35)
ALL INJURIES	**172 (100)**	**4.14 (3.6-4.8)**	**4 (3.48-4.69)**	**17 (14.42-19.45)**	**76 (100)**	**1.71 (1.4-2.1)**	**5 (4.26-6.67)**	**9 (7.26-11.38)**	**75 (100)**	**1.81 (1.4-2.3)**	**15 (12.06-18.96)**	**27 (21.79-34.27)**

Table 5.4: Injury Incidence for Male Dancers by Year and Time Loss (partial or full withdrawal)

	Year 1				Year 2				Year 3			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)
Partial withdrawal	147 (80)	3.83 (3.3-4.5)	6 (5.04-6.96)	23 (19.28-26.64)	73 (68)	1.64 (1.30-2.10)	4 (3.17-5.01)	7 (5.19-8.21)	74 (74)	1.66 (1.30-2.10)	6 (4.41-6.96)	9 (7.32-11.55)
Full withdrawal	36 (20)	0.94 (0.68-1.30)	24 (16.97-32.62)	22 (15.90-30.56)	34 (32)	0.76 (0.55-1.07)	27 (19.17-37.54)	21 (14.62-28.64)	25 (25)	0.56 (0.38-0.83)	17 (11.38-24.92)	9 (6.38-13.98)
ALL INJURIES	**183 (100)**	**4.76 (4.1-5.5)**	**9 (8.12-10.85)**	**44 (38.68)**	**107 (100)**	**2.40 (2.00-2.90)**	**11 (9.30-13.59)**	**27 (22.33-32.62)**	**99 (100)**	**2.22 (1.80-2.70)**	**8 (6.89-10.22)**	**19 (15.31-22.70)**

5.3.2 Rank

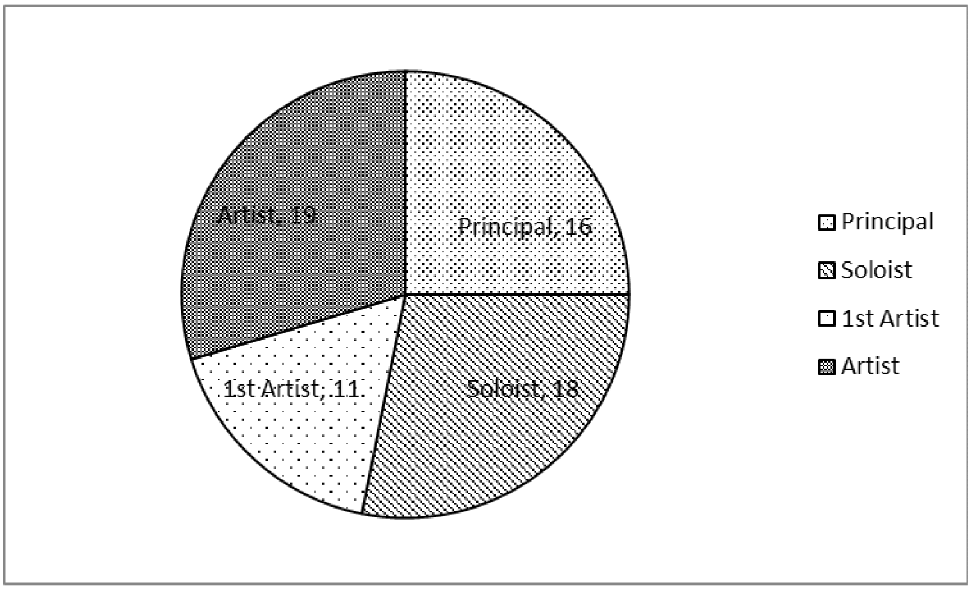
All dancers were assigned a different rank for each of the years within the study based on their position within the company. The rank a dancer held largely influenced the dancing demands placed on them (Twitchett et. al. 2009).

In all years the female artist dancers experienced the highest incidence and the 1^{st} artists the lowest incidence of injury. The severity per dancer was higher for female artists and soloists, and lowest for 1^{st} artists in Year 1 and 2. In Year 3, principals recorded the highest severity per dancer with 1^{st} artists still recording the lowest severity per dancer. In female principal dancers the incidence of injury reduced by 53.24% between Year 1 and Year 2, and by a further 14.47% between Year 2 and Year 3. Female soloist injury incidences reduced by 68.90% between Year 1 and Year 2, but increased by 5.10 % between Year 2 and 3. Similarly, the incidence of injury to 1^{st} artists (by 68.90%) and artists (by 58.7%) reduced between Year 1 and Year 2 but increased between Year 2 and Year 3 (1^{st} Artists: 8.46%; Artists: 8.06%) (Table 5.5).

Table 5.5: Injury Incidence for Female Dancers by Year and Rank

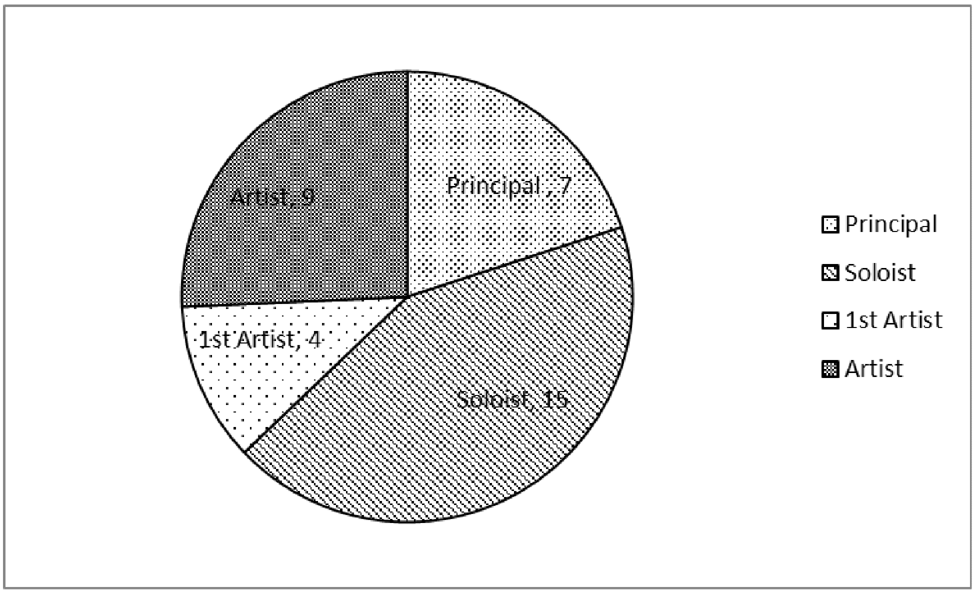
	Year 1					Year 2					Year 3				
	No.	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	No.	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	No.	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)
Principal	4	20 (11)	3.25 (2.1-5.0)	5 (3.10-7.44)	16 (10.07-24.20)	3	7 (9)	1.52 (0.7-3.2)	4 (2.04-8.99)	7 (3.10-13.65)	3	6 (8)	1.30 (0.6-2.9)	36 (16.17-80.13)	47 (21.05-104.27)
Soloist	7	45 (26)	4.18 (3.1-5.6)	4 (3.29-5.89)	18 (13.74-24.65)	8	16 (21)	1.30 (0.8-2.1)	11 (6,85-18.26)	15 (8.92-23.76)	9	19 (25)	1.37 (0.9-2.2)	24 (15.54-38.20)	33 (21.35-52.47)
1st Artist	5	18 (11)	2.34 (1.5-3.7)	5 (3.01-7.58)	11 (7.05-17.06)	6	11 (15)	1.19 (0.7-2.2)	3 (1.86-6.07)	4 (2.22-7.24)	4	8 (12)	1.30 (0.7-2.6)	3 (1.69-6.75)	4 (2.20-8.78)
Artist	11	89 (52)	5.26 (4.3-6.5)	4 (2.88-4.36)	19 (15.14-22.93)	12	42 (55)	2.28 (1.7-3.1)	4 (2.80-5.12)	9 (6.37-11.67)	11	42 (56)	2.48 (1.8-3.4)	10 (7.53-13.79)	25 (18.71-34.25)
Total	**27**	**172 (100)**	**4.14 (3.6-4.8)**	**4 (3.48-4.69)**	**17 (14.42-19.45)**	**29**	**76 (100)**	**1.71 (1.4-2.1)**	**5 (4.26-6.67)**	**9 (7.26-11.38)**	**27**	**75 (100)**	**1.81 (1.4-2.3)**	**15 (12.06-18.96)**	**27 (21.79-34.27)**

Calculation of days lost per 1000hrs dancing demonstrated a greater risk to artists, followed by soloists, principals and 1st artists in Year 1 (Fig 5.5) but this was not statistically significant. Year 2 indicated a greater risk to soloists, followed by artists, principals and significantly greater than 1st artists (Fig 5.6). In Year 3 greater risk was recorded in principals, followed by soloists, artists and significantly greater than 1st artists (Fig 5.7).



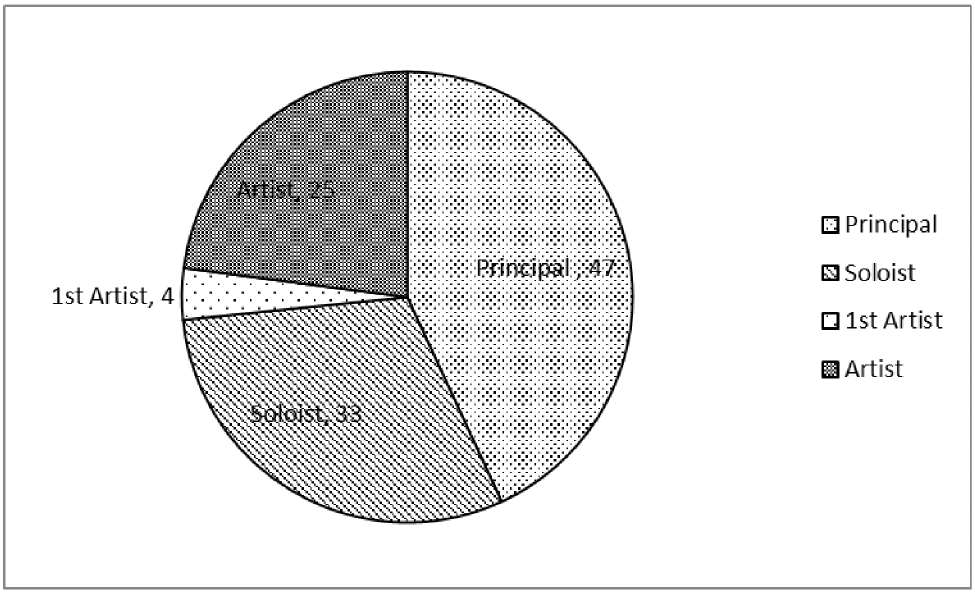
Legend: All figures represent days lost per 1000hrs dancing

Figure 5.5: Female Risk in days lost per 1000hrs dancing, Year 1



Legend: All figures represent days lost per 1000hrs dancing

Figure 5.6: Female Risk in days lost per 1000hrs dancing, Year 2



Legend: All figures represent days lost per 1000hrs dancing

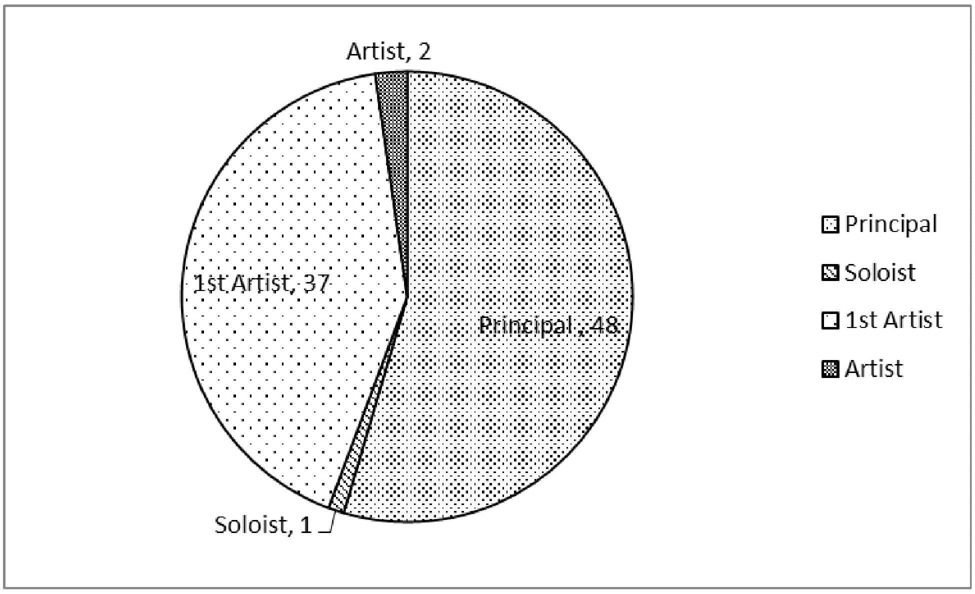
Figure 5.7: Female Risk in days lost per 1000hrs dancing, Year 3

In all years the male principals, 1st artists and artists all experienced a much higher incidence of injury compared with the soloists, while male 1st artists and principals recorded the highest severity per dancer (Table 5.6). Principals recorded a non-significant reduction in injury incidence of 34.23% between Year 1 and Year 2, and by a further non-significant reduction of 36.54% between Year 2 and 3. Male soloists recorded a non-significant increase of 2.56% between Year 1 and Year 2, and a further non-significant increase of 24.51% between Year 2 and Year 3. 1st Artists recorded a significant reduction in injury incidence between Year 1 and Year 2, but recorded a non-significant increase of 8.54% between Year 2 and Year 3. Male artists consistently recorded reductions in injury incidence, with a significant reduction of 49.72% between Year 1 and 2, and a non-significant 3.70% between Year 2 and 3 (Table 5.6).

Table 5.6: Injury Incidence for Male Dancers by Year and Rank

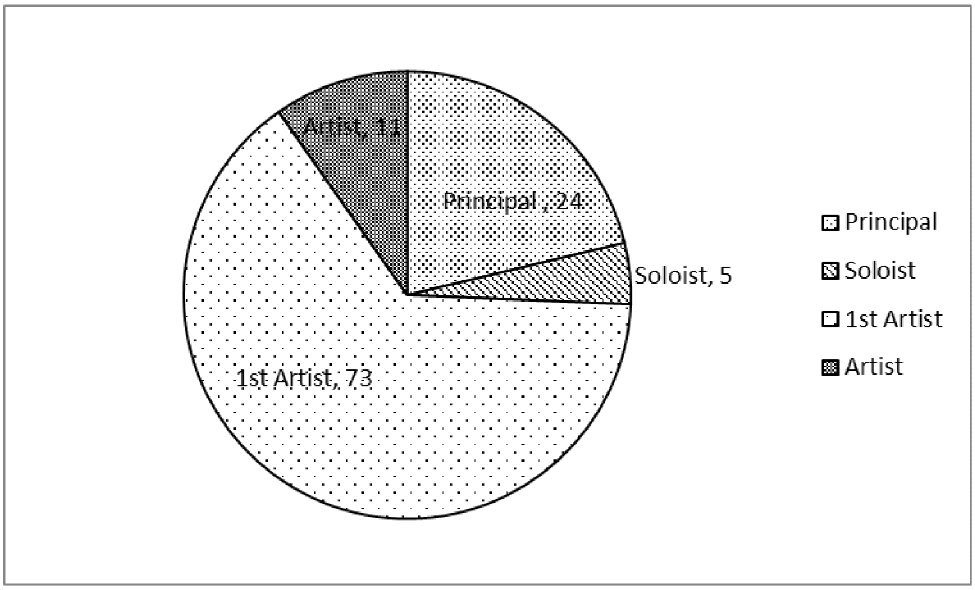
	Year 1					Year 2					Year 3				
	No.	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	No.	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	No.	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)
Principal	4	32 (17)	5.20 (3.7-7.4)	15 (10.67-21.34)	48 (34.2-68.3)	4	21 (20)	3.42 (2.2-5.2)	7 (4.66-10.96)	24 (15.91 - 37.42)	3	10 (10)	2.17 (1.2-4.0)	6 (2.96-10.22)	12 (6.42-22.17)
Soloist	4	7 (4)	1.14 (0.5-2.4)	2 (1.02-4.49)	1 (0.16-0.68)	5	9 (8)	1.17 (0.6-2.3)	4 (2.02-7.47)	5 (2.37-8.75)	8	19 (19)	1.55 (1.0-2.4)	9 (5.74-14.11)	14 (8.87-21.80)
1st Artist	5	45 (25)	5.86 (4.4-7.8)	14 (10.35-18.57)	37 (27.7-49.7)	7	23 (21)	2.14 (1.4-3.2)	34 (22.82-51.69)	73 (48.79-110.50)	5	18 (18)	2.34 (1.5-3.7)	16 (10.26-25.84)	38 (24.02-60.51)
Artist	12	99 (54)	5.37 (4.4-6.5)	6 (9.94-7.33)	2 (1.29-1.91)	13	54 (51)	2.70 (2.1-3.5)	4 (3.23-5.51)	11 (8.74-14.90)	13	52 (53)	2.60 (2.0-3.4)	6 (4.57-7.87)	16 (11.90-20.49)
Total	**25**	**183 (100)**	**4.76 (4.1-5.5)**	**9 (8.12-10.85)**	**16 (13.80-18.44)**	**29**	**107 (100)**	**2.40 (2.0-2.9)**	**11 (9.30-13.59)**	**27 (22.33-32.62)**	**29**	**99 (100)**	**2.22 (1.8-2.7)**	**8 (6.89-10.22)**	**19 (15.31-22.70)**

Risk, measured as day's absence per 1000hrs dancing demonstrated a significantly greater risk to Principals and 1st artists, compared to artists and soloists in Year 1 (Fig 5.8). Year 2 indicated a significantly greater risk to 1st Artists, compared to principals, artists and soloists (Fig 5.9). In Year 3 significantly greater risk was recorded in 1st artists, compared to artists, soloists and principals (fig 5.10).



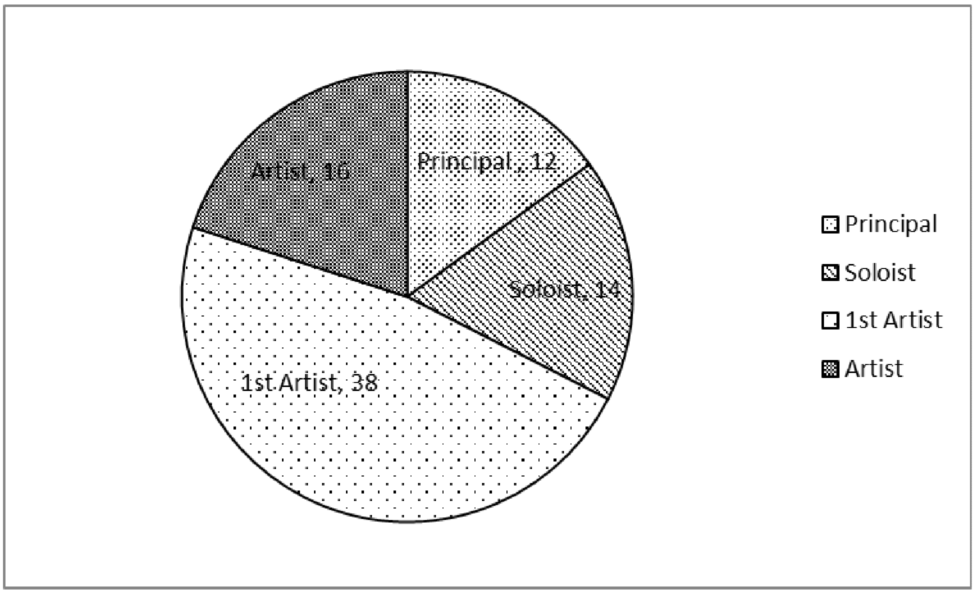
Legend: All figures represent days lost per 1000hrs dancing

Figure 5.8: Male Risk in days lost per 1000hrs dancing, Year 1



Legend: All figures represent days lost per 1000hrs dancing

Figure 5.9: Male Risk in days lost per 1000hrs dancing, Year 2



Legend: All figures represent days lost per 1000hrs dancing

Figure 5.10: Male Risk in days lost per 1000hrs dancing, Year 3

5.3.3 Activity

Dancers performed in 145 performances of 15 different shows in Year 1, 143 performances of 18 different shows in Year 2, and 142 performances of 20 different shows in Year 3. The performance periods were spread in blocks of between 2 and 6 weeks over the performance year, averaging 7 performances per week during performance weeks. Rehearsal and class (practice or training) took place throughout the year (excluding holiday periods) for 6 days of the week including during performance periods. The dancers had a one week mid-season break and a further 5 week break over the summer for each of the study years. The typical number of dance hours per week (performance and practice) was 36 hours throughout the study period.

The highest incidence of injuries for female dancers in Year 1 and 2 occurred during class (Year 1: 4.94/1000hrs dance; Year 2: 3.30/1000hrs dance), and performance (2.4/1000hrs dance) in Year 3. The greatest percentage of time loss resulted from performances (47%) in Year 1 and class in Year 2 (71%) and Year 3 (68%) (Table 5.7). A reduction of 33% in injury incidence was recorded for female dancers between Year 1 and Year 2, with a further reduction of 44.54% between Year 2 and Year 3. Both rehearsal and performance related injury incidence reduced between Year 1 and Year 2 for female dancers (rehearsal: 47.82%; performance: 28.90%) and increased between Year 2 and Year 3 (rehearsal: 33.33%; 48.96%) but still remained lower than in Year 1 (Table 5.7).

The highest incidence of injuries for male dancers in Year 1 occurred during class (7.54/1000hrs dance) and accounted for the greatest percentage of time loss (53%). In Year 2 and 3 the highest incidence of injuries and percentage time loss resulted from performance related injuries (Year 2: 3.69/1000hrs dance; Year 3: 3.58/1000hrs dance) (Table 5.8). Class related injury incidences reduced between Year 1 and Year 2 by 74.80% in male dancers, while rehearsal and performance related injuries incidences reduced in between Year 1 and 2 (rehearsal: 47.82%; performance: 28.90%) and Year 2 and Year 3 (rehearsal: 39.74%; performance: 2.98%) (Table 5.8).

Table 5.7: Injury Incidence for Female Dancers by Year and Activity (Class/Rehearsal/Performance)

	Year 1				**Year 2**				**Year 3**			
	Female				**Female**				**Female**			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)
Class	46 (33)	4.94 (3.7-6.6)	4 (2.87-5.11)	19 (14.15-25.23)	33 (52)	3.30 (2.3-4.6)	7 (5.06-10.02)	23 (16.70-33.04)	17 (26)	1.83 (1.1-2.9)	32 (19.97-51.66)	59 (36.44-94.29)
Rehearsal	58 (41)	2.43 (1.9-3.1)	2 (1.83-3.06)	6 (4.44-7.42)	20 (31)	0.78 (0.5-1.2)	2 (1.03-2.48)	1 (0.81-1.93)	28 (13)	1.17 (0.8-1.7)	5 (3.60-7.55)	6 (4.22-8.86)
Performance	37 (26)	4.45 (3.2-6.1)	7 (5.37-10.22)	33 (23.87-45.48)	11 (17)	1.23 (0.7-2.2)	6 (3.32-10.83)	7 (4.09-13.34)	20 (31)	2.41 (1.6-3.7)	6 (3.68-8.84)	14 (8.84-21.25)
ALL INJURIES	**141 (100)**	**3.40 (2.9-4.0)**	**4 (5.53-4.91)**	**14 (11.99-16.68)**	**64 (100)**	**1.44 (1.1-1.8)**	**5 (4.07-6.65)**	**7 (5.85-9.54)**	**65 (100)**	**1.57 (1.2-2.0)**	**12 (9.72-15.81)**	**19 (15.23-24.77)**

Table 5.8: Injury Incidence for Male Dancers by Year and Activity (Class/Rehearsal/Performance)

	Year 1				Year 2				Year 3			
	Male				**Male**				**Male**			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)
Class	65 (38)	7.54 (5.9-9.6)	13 (10.54-17.15)	101 (79.46-129.22)	19 (21)	1.90 (1.20-3.00)	9 (5.77-14.19)	17 (10.97-26.95)	32 (36)	3.20 (2.30-4.50)	8 (5.33-10.65)	24 (17.03-34.06)
Rehearsal	66 (39)	2.99 (2.3-3.8)	4 (3.36-5.44)	13 (10.02-16.24)	40 (43)	1.56 (1.10-2.10)	8 (5.54-10.29)	12 (8.64-16.06)	24 (28)	0.94 (0.60-1.40)	10 (6.42-14.30)	9 (6.01-13.39)
Performance	40 (23)	5.19 (3.8-7.1)	13 (9.17-17.04)	65 (47.63-88.53)	33 (36)	3.69 (2.60-5.20)	20 (14.39-28.47)	75 (53.17-105.20)	32 (36)	3.58 (2.50-5.10)	10 (7.01-14.01)	35 (25.10-50.19)
ALL INJURIES	**171(100)**	**4.45 (3.8-5.2)**	**10 (8.34-11.25)**	**43 (37.10-50.07)**	**92 (100)**	**2.06 (1.70-2.50)**	**12 (10.12-15.23)**	**26 (20.89-31.43)**	**88 (100)**	**1.97 (1.60-2.40)**	**9 (7.27-11/04)**	**18 (14.35-21.79)**

5.3.4 Recurrent Injuries

The majority of female injuries in Year 1 were first episodes (49%), which accounted for 55% of the time loss, followed by recurrent injuries (40%) which accounted for 34% of the time loss. In Year 2, 7% of the injuries to female dancers were first episodes, accounting for 56% of the time loss, with recurrent injuries accounting for 36% of the injuries and 42% of the time loss. In Year 3 the first-episodes accounted for 11% of the female injuries and 92% of the time loss, with 25% of the injuries recurrent accounting for 7% of the time loss (Table 5.9). Female dancers recorded a decrease in injury incidence for 1st episode injuries between Year 1 and Year 2 (94.63%), but an increase between Year 2 and Year 3 (42%). An increase in exacerbations was noted between both Year 1 and Year 2 (53.53%) and Year 2 and Year 3 (14.65%) for female dancers. A reduction in recurrent injuries was recorded between Year 1 and Year 2 (68.87%) and Year 2 and Year 3 (8.51%) for females (Table 5.9).

In Year 1, 10% of male injuries were first-episodes, which accounted for 65% of the time loss, with recurrent injuries representing 32% of all injuries and accounting for 22% of the time loss. In Year 2, 8% of the injuries were first episodes, resulting in 55% of the time loss, while recurrent injuries totalled 20% of the injuries and in 44% of the time loss. In Year 3, first-episodes were 13% of all male injuries and 64% of the time loss with recurrent injuries accounting for 19% of injuries and 7% of time loss (Table 5.10). Between Year 1 and Year 2 for male dancers, first-episodes reduced by 59.18%, but increased again by 31.03% between Year 2 and Year 3. Exacerbations displayed a similar pattern, with a reduction in incidence noted between Year 1 and Year 2 of 37.31%, followed by an increase of 13.29% between Year 2 and Year 3. Recurrent injuries reduced between Year 1 and Year 2 (68.87%) and Year 2 and Year 3 (8.51%) (Table 5.10).

Table 5.9: Injury Incidence for Female Dancers by Year and Episode (First episode/Exacerbation/Recurrence)

	Year 1				Year 2				Year 3			
	Female				Female				Female			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)
First-Episode	85 (49)	2.05 (1.7-2.5)	5 (3.65-5.59)	9 (7.48-11.45)	5 (6)	0.11 (0.00-0.30)	45 (18.73-108.12)	5 (2.10-12.13)	8 (11)	0.19 (0.10-0.40)	130 (65.14-260.45)	25 (12.56-50.21)
Exacerbation	19 (11)	0.46 (0.3-0.7)	4 (2.52-6.19)	2 (1.15-2.83)	44 (58)	0.99 (0.70-1.3)	0 (0.19-0.34)	0 (0.18-0.33)	48 (64)	1.16 (0.90-1.50)	0 (0.25-0.44)	0 (0.29-0.51)
Recurrence	68 (40)	1.64 (1.29-2.08)	4 (2.74-4.40)	6 (4.48-7.21)	27 (36)	0.61 (0.42-0.88)	6 (4.29-9.13)	4 (2.60-5.53)	19 (25)	0.46 (0.29-0.72)	4 (2.55-6.27)	2 (1.17-2.87)
ALL INJURIES	**172 (100)**	**4.14 (3.6-4.8)**	**4 (3.48-4.69)**	**17 (14.42-19.45)**	**76 (100)**	**1.71 (1.4-2.1)**	**5 (4.26-6.67)**	**9 (7.26-11.38)**	**75 (100)**	**1.81 (1.4-2.3)**	**15 (12.06-18.96)**	**27 (21.79-34.27)**

Table 5.10: Injury Incidence for Male Dancers by Year and Episode (First episode/Exacerbation/Recurrence)

	Year 1				Year 2				Year 3			
	Male				Male				Male			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)
First-Episode	19 (10)	0.49 (0.3-0.8)	59 (37.67-92.58)	29 (18.63-45.78)	9 (8)	0.20 (0.10-0.40)	73 (38.10-140.73)	15 (7.69-28.42)	13 (13	0.29 (0.20-0.50)	41 (23.76-70.48)	12 (6.93-20.56)
Exacerbation	106 (58)	2.76 (2.3-3.3)	2 (1.71-2.50)	6 (4.71-6.89)	77 (72)	1.73 (1.40-2.20)	0 (0.20-0.31)	0 (0.34-0.59)	67 (67)	1.50 (1.20-1.90)	4 (2.82-4.55)	5 (4.24-6.84)
Recurrence	58 (32)	1.51 (1.17-1.95)	7 (5.03-8.41)	10 (7.59-12.69)	21 (20)	0.47 (0.31-0.72)	25 (16.30-38.34)	12 (7.68-18.07)	19 (20)	0.43 (0.27-0.67)	3 (1.98-7.87)	1 (0.84-2.08)
ALL INJURIES	**183 (100)**	**4.76 (4.1-5.5)**	**9 (8.12-10.85)**	**45 (38.68-51.68)**	**107 (100)**	**2.40 (2.00-2.90)**	**11 (9.30-13.59)**	**27 (22.33-32.62)**	**99 (100)**	**2.22 (1.80-2.70)**	**8 (6.89-10.22)**	**19 (15.31-22.70)**

5.3.5 Injury Type and Causation

The incidence of female overuse injuries was consistently higher than the traumatic injuries (Year 1: 2.82/1000hrs dance; Year 2: 1.08/1000hrs dance; Year 3: 1.2/1000hrs dance) and accounted for a greater percentage of time loss (Year 1: 54%; Year 2: 63%; Year 3: 75%) (Table 5.11). Female dancers recorded reductions in both overuse and traumatic injuries between Year 1 and Year 2 (overuse: 61.70%; traumatic: 52.63%), while between Year 2 and Year 3, overuse injuries increased by 8.47%, with traumatic injuries remaining the same.

The incidence of male overuse injuries was higher in Year1 (2.84 /1000hrs dance) and accounted for a greater percentage of time loss (58%), while traumatic injuries were higher in Year 2 (1.48/1000hrs dance) and Year 3 (1.35/1000hrs dance) and accounted for the greatest percentage of time loss (Year 2: 80%; Year 3: 51%) (Table 5.12). Male dancers recorded reductions in both overuse and traumatic injuries between Year 1 and Year 2 (overuse: 67.60%; traumatic: 23.31%) and Year 2 and Year 3 (overuse: 5.43%; traumatic: 8.78%) (Table 5.12).

Table 5.11: Injury Incidence for Female Dancers by Year and Type (Overuse/Traumatic)

	Year 1				**Year 2**				**Year 3**			
	Female				**Female**				**Female**			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)
Overuse	117 (68)	2.82 (2.4-3.4)	3 (2.70-3.87)	9 (7.60-10.92)	48 (63)	1.08 (0.8-1.4)	5 (4.00-7.05)	6 (4.31-7.59)	49 (65)	1.18 (0.9-1.6)	17 (13.03-22.82)	20 (15.39-26.94)
Traumatic	55 (32)	1.33 (1.0-1.7)	6 (4.43-7.51)	8 (5.86-9.95)	28 (37)	0.63 (0.4-0.9)	5 (3.70-7.76)	3 (2.32-4.87)	26 (35)	0.63 (0.4-0.9)	11 (7.57-16.33)	7 (4.74-10.23)
ALL INJURIES	**172 (100)**	**4.14 (3.6-4.8)**	**4 (3.48-4.69)**	**17 (14.42-19.45)**	**76 (100)**	**1.71 (1.4-2.1)**	**5 (4.26-6.67)**	**9 (7.26-11.38)**	**75 (100)**	**1.81 (1.4-2.3)**	**15 (12.06-18.96)**	**27 (21.79-34.27)**

Table 5.12: Injury Incidence for and Male Dancers by Year and Type (Overuse/Traumatic)

	Year 1				Year 2				Year 3			
	Male				Male				Male			
	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)	Number of injuries (% of all injuries)	Injury incidence/ 1,000 hrs dancing (95%CI)	Mean Severity (Days) (95%CI)	Days absence/ 1,000 hrs (95%CI)
Overuse	110 (60)	2.84 (2.4-3.5)	9 (7.64-11.12)	26 (21.68-31.56)	41 (38)	0.92 (0.70-1.02)	6 94.29-7.92)	5 (3.95-9.28)	39 (40)	0.87 (0.60-1.20)	11 (7.70-14.42)	9 (6.74-12.62)
Traumatic	73 (40)	1.93 (1.5-2.4)	10 (7.67-12.10)	19 (14.77-23.30)	66 (62)	1.48 (1.20-1.90)	15 (11.48-18.59)	22 (16.99-27.53)	60 (60)	1.35 (1.00-1.70)	7 (5.44-9.02)	9 (7.32-12.14)
ALL INJURIES	**183 (100)**	**4.76 (4.1-5.5)**	**9 (8.12-10.85)**	**45 (38.68-51.68)**	**107 (100)**	**2.40 (2.00-2.90)**	**11 (9.30-13.59)**	**27 (22.33-32.62)**	**99 (100)**	**2.22 (1.80-2.70)**	**8 (6.89-10.22)**	**19 (15.31-22.70)**

In classifying the causation of injuries, female dancers recorded higher incidences of intrinsic injuries (Year 1: 2.65/1000hrs dance; Year 2: 1.14/1000hrs dance; Year 3: 1.1/1000hrs dance) and greater percentages of time loss (Year 1: 70%; Year 2: 74%; Year 3: 65%) (Figure 5.11). Both extrinsic and intrinsic causation classified injuries in female dancers reduced between Year 1 and Year 2 by 62.41% and 56.98% respectively. Extrinsic injuries increased by 20.00% between Year 2 and Year 3, while intrinsic injuries reduced again by 2.63%.

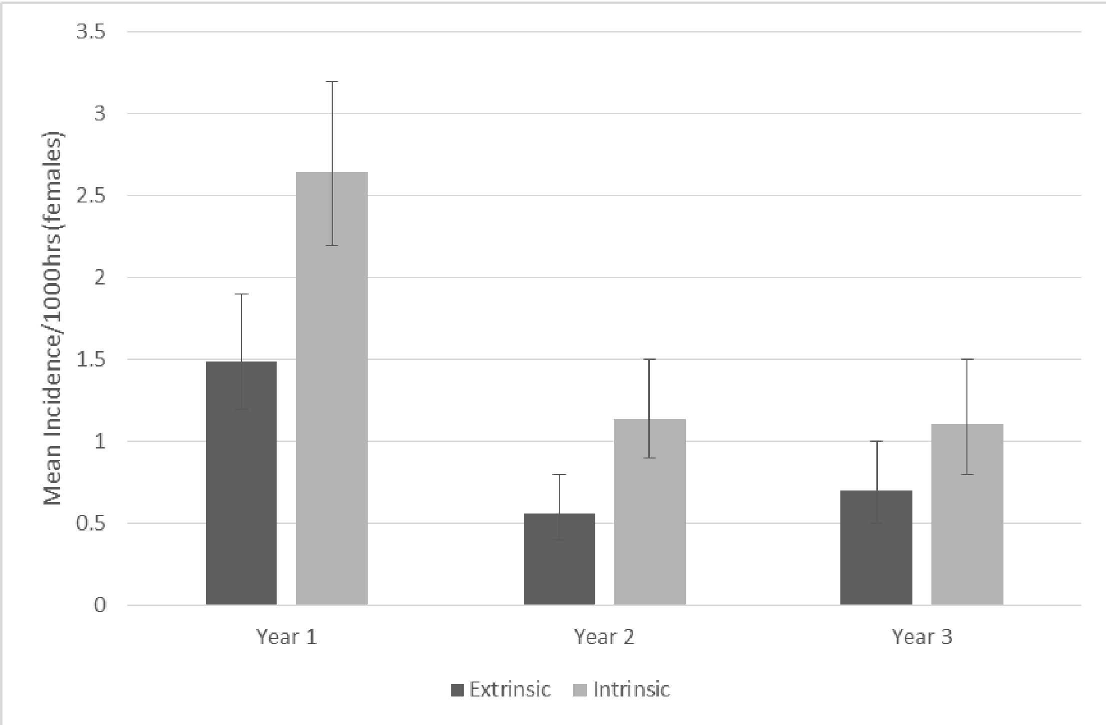


Figure 5.11: Injury Incidence for Female Dancers by Year and Type (Intrinsic/Extrinsic)

In classifying the causation of injuries in male dancers, there were higher incidences of intrinsic injuries (Year 1: 3.12/1000hrs dance; Year 2: 1.66/1000hrs dance; Year 3: 1.66/1000hrs dance) and greater percentages of time loss (Year 1: 80%; Year 2: 87%; Year 3: 85%) recorded (Figure 5.12). Both extrinsic and intrinsic injuries were reduced between Year 1 and Year 2 by 54.87% and 46.79% respectively, while extrinsic injuries continued to reduce by a further 23.32% with intrinsic injury incidence remaining the same between Year 2 and Year 3.

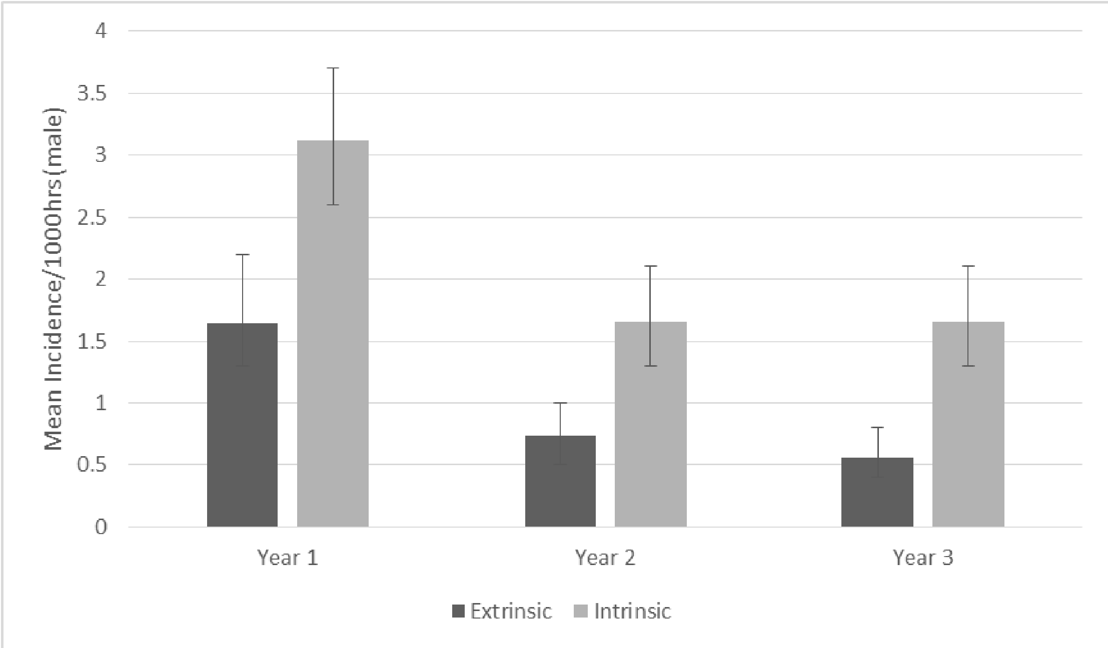


Figure 5.12: Injury Incidence for Male Dancers by Year and Type (Intrinsic/Extrinsic)

5.3.6 Body and Injury Groupings

5.3.6.1 Female Body Groupings

In Year 1, the highest incidence of injuries for female dancers arose from the lower leg (0.72/1000hrs dance), lumbar region (0.65/1000hrs dance) and ankle (0.60/1000hrs dance), with ankle injuries accounting for the greatest percentage of time loss (17%), followed by lower leg (16%) and lumbar region (15%). In Year 2 the highest incidence arose from ankle injuries (0.43/1000hrs dance), head and neck (0.22/1000hrs dance) and lumbar region (0.20/1000hrs dance) and pelvis/hip (0.20/1000hrs), with the greatest percentage time loss resulting from ankle injuries (46%), followed by knee (11%) and pelvis/hip (10%). In Year 3 ankle injuries recorded the highest incidence (0.51/1000hrs dance) followed by foot (0.27/1000hrs dance) and lumbar region (0.22/1000hrs), with the foot (38%) and lumbar regions (38%) accounting for the greatest percentage of time loss. Within the body regions that resulted in the higher injury incidences, all experienced a reduction in incidence between Year 1 and Year 2 (head and neck: 58.49%; lumbar region: 69.23%; pelvis and hip: 31.03%; knee: 59.09%; lower leg: 75.00%; ankle: 28.33%; foot: 74.41%). With the exception of the head and neck region, that reported a continued decrease by a further 54.54%, the other higher incidence body regions all reported an increase between Year 2 and Year 3 (lumbar region: 9.09%; pelvis and hip: 75.00%; knee: 25.00%; lower leg: 25.00%; ankle: 15.68%; foot: 59.25%) (Figure 5.13).

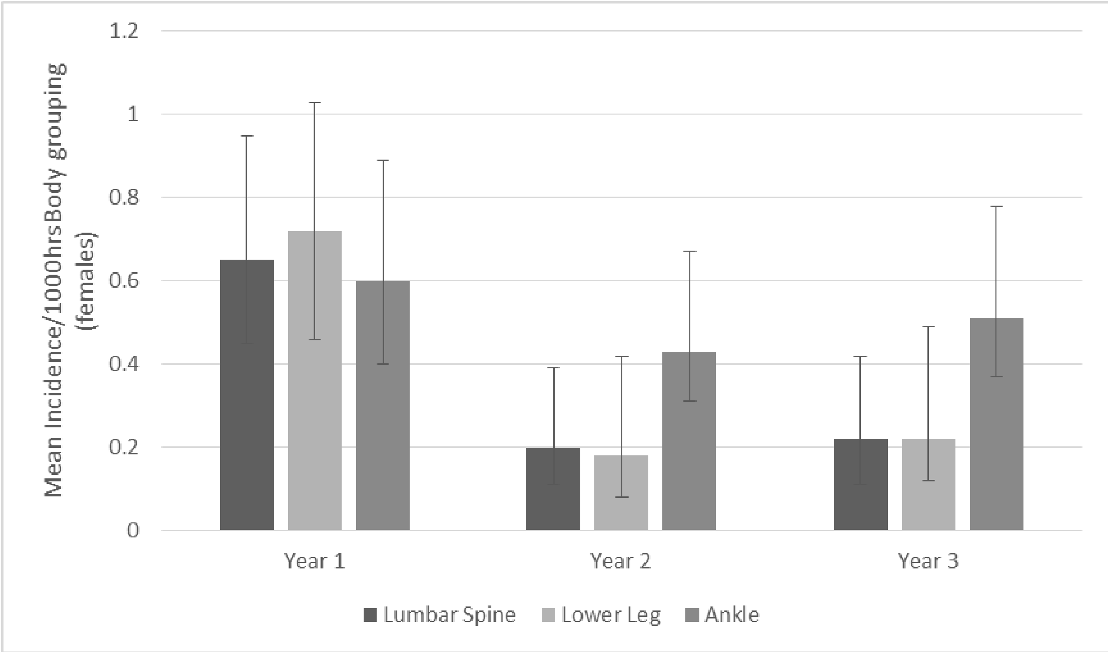


Figure 5.13: Injury Incidence for Female Dancers by Year and Highest Ranking Year 1 Body Grouping

5.3.6.2 Male Body Groupings

In Year 1, the highest incidence of injuries for male dancers arose from the lower leg (0.91/1000hrs dance), ankle (0.62/1000hrs dance) and lumbar region (0.57/1000hrs dance), with lower leg injuries accounting for the greatest percentage of time loss (46%), followed by ankle (12%) and knee (11%). In Year 2 foot injuries (0.43/1000hrs dance), lumbar region (0.34/1000hrs dance) and ankle injuries (0.27/1000hrs dance) recorded the highest incidences. The greatest percentage time loss was as a result of ankle (43%) and wrist (14%) injuries. Ankle (0.34/1000hrs dance), lumbar (0.27/1000hrs dance), knee (0.27/1000hrs dance) and thoracic/rib (0.27/1000hrs dance) region injuries were the highest in Year 3, with the greatest percentage time loss resulting from the injuries to the lumbar (28%) and ankle (20%). Within the body regions that recorded the highest incidences of injury, with the exception of the foot, where an increase of 16.27% was recorded, all other body regions recorded a decrease in injury incidence between Year 1 and Year 2 (thoracic region: 95.91%; lumbar region: 40.35%; knee: 34.09%; lower leg: 75.82%; ankle: 56.45%). Between Year 2 and Year 3, the incidence of lower leg injuries remained constant, while decreases were noted in lumbar (20.58%), knee (6.89%) and foot (37.20%) regions. An increase was noted in ankle (20.58%) and thoracic (92.59%) region injuries (Figure 5.14).

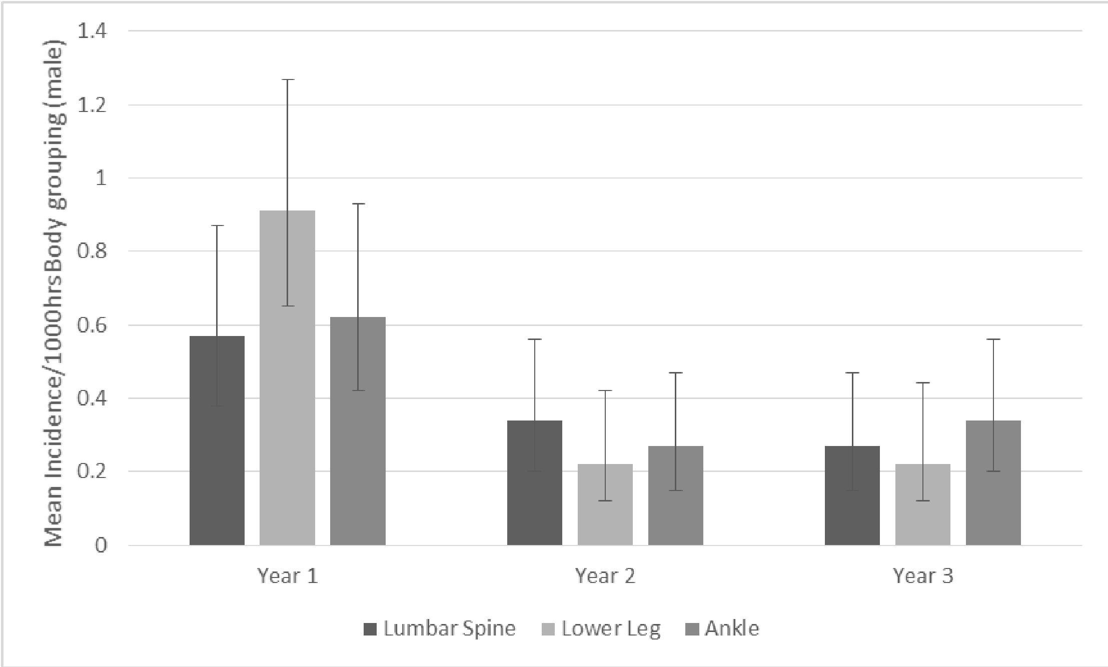


Figure 5.14: Injury Incidence for Male Dancers by Year and Highest Ranking Year 1 Body Grouping

5.3.6.3 Female Injury Grouping

Higher incidences for ankle instability/ ligament sprain including sinus tarsi was recorded for female dancers throughout the study period (Year 1: 0.27/1000hrs dance; Year 2: 0.18/1000hrs dance; Year 3: 0.22/1000hrs dance), with higher percentage time loss in Year 1 (10%) and Year 2 (14%). Cervical facet joint dysfunction/ nerve root pathology (0.34/1000hrs dance) and lumbar facet joint dysfunction/ nerve root pathology (0.29/1000hrs dance), along with foot muscle spasm/strain/tear (0.22/1000hrs dance) recorded higher incidences as well as percentage time loss, 7%, 9% and 8% respectively in Year 1. Higher incidences for gluteal/hip (including Psoas) muscle spasm/strain/tear (0.16/1000hrs dance) and lumbar muscle spasm/strain/tears (0.13/1000hrs dance) were recorded in Year 2. The highest percentage time loss resulted from ankle impingements (27%), although the incidence for ankle impingement was very low (0.04/1000hrs dance). In Year 3, both calf muscle spasm/strain/tear and sprain foot/toe joint recorded the higher incidences (0.19/1000hrs dance), while stress fracture incl. tibia/metatarsal recorded the highest percentage time loss (35%), but only a low incidence (0.02/1000hrs dance).

Examining the injuries that reported higher incidences of injury, between Year 1 and Year 2 a reduction was recorded in cervical facet joint dysfunction/ nerve root pathology (97.62%), lumbar facet joint dysfunction/ nerve root pathology (97.97%), lumbar muscle spasm/strain/tears (51.85%), gluteal/hip (including Psoas) (15.78%), and calf muscle spasm/strain/tear (35.29%), while between Year 2 and Year 3 reductions were noted in cervical facet joint dysfunction/ nerve root pathology (71.42%), lumbar muscle spasm/strain/tears (23.77%), and gluteal/hip (including Psoas) (100%), while increases were noted in lumbar facet joint dysfunction/ nerve root pathology (41.66%), calf muscle spasm/strain/tear (42.10%), ankle instability/ ligament sprain including sinus tarsi (18.18%), and sprain foot/toe joint (78.94%) (Figure 5.15).

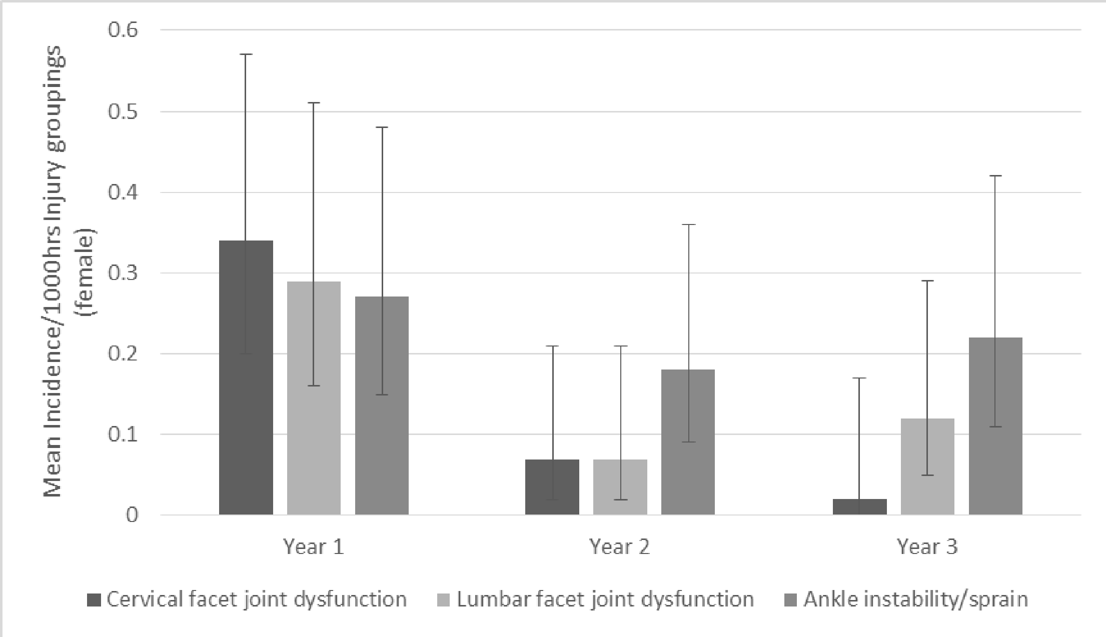


Figure 5.15: Injury Incidence for Female Dancers by Year and Highest Ranking Year 1 Injury Grouping

5.3.6.4 Male Injury Grouping

Male dancers recorded the highest incidence of injuries for thoracic facet joint/rib dysfunction and lumbar muscle spasm/strain/tears (0.34/1000hrs dance), with 0.29/1000hrs recorded for medial tibial stress syndrome in Year 1. The highest percentage time loss was recorded for stress fracture incl. tibia/metatarsal (35%), with a low incidence (0.10/1000hrs dance). In Year 2 sprains to the foot/toe joint resulted in the highest incidence (0.20/1000hrs dance), followed by shoulder muscle/joint spasm/strain/tear/sprain and lumbar facet joint dysfunction/ nerve root pathology (0.18/1000hrs dance). The highest percentage time loss resulted from ankle instability/ligament sprain incl. sinus tarsi (41%). In Year 3 foot muscle spasm/strain/tear recorded the highest incidence (0.20/1000hrs dance) with a low percentage time loss (8%). The highest percentage time loss resulted from lumbar muscle spasm/strain/tears (25%) with a comparatively low incidence (0.13/1000hrs dance).

Of the injuries that recorded higher incidences, reductions were noted between Year 1 and Year 2 in thoracic facet joint/rib dysfunction (94.11%), lumbar muscle spasm/strain/tears (61.76%), medial tibial stress syndrome (68.96%), ankle instability/ligament sprain including sinus tarsi (87.50%) and foot muscle spasm/strain/tear (11.11%), while increases were noted in shoulder muscle/joint spasm/strain/tear/sprain (27.77%), lumbar facet joint dysfunction/ nerve root pathology (27.77%). Between Year 2 and Year 3, reductions in incidences were noted in medial tibial stress syndrome (100%), shoulder muscle/joint spasm/strain/tear/sprain (50.00%) and lumbar facet joint dysfunction/ nerve root pathology (27.77%), with increases noted in thoracic facet joint/rib dysfunction (84.61%), foot muscle spasm/strain/tear (20.00%) and ankle instability/ligament sprain including sinus tarsi (81.81%). Lumbar muscle spasm/strain/tears remained constant between Year 2 and Year 3 (Figure 5.16).

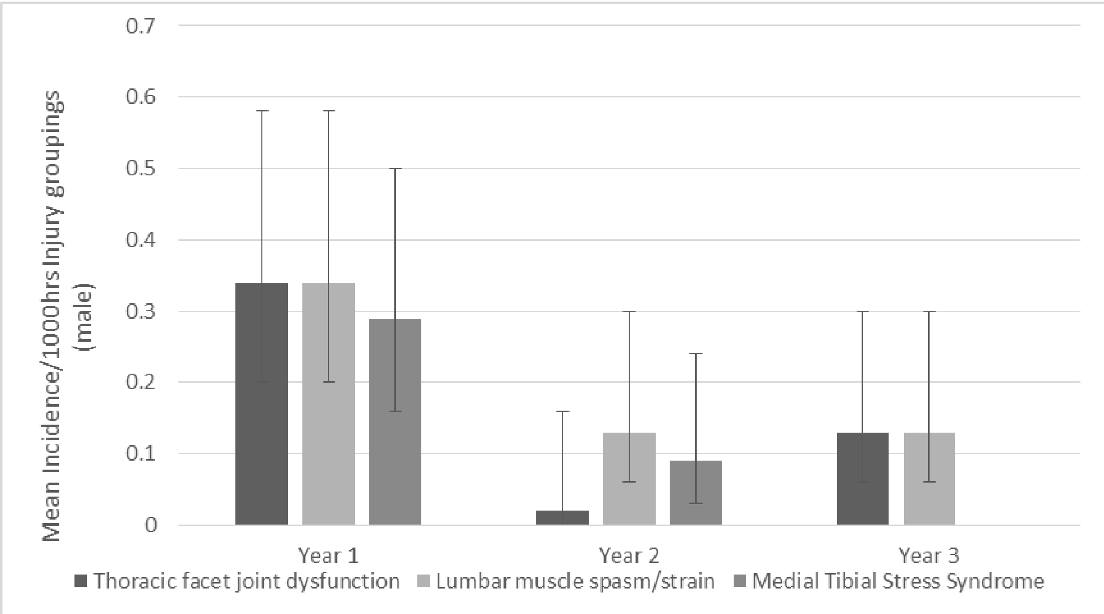


Figure 5.16: Injury Incidence for Male Dancers by Year and Highest Ranking Year 1 Injury Grouping

5.4 Discussion

The objective of this study was to observe injury incidence and severity in a cohort of professional ballet dancers over a three year period with the aim of reducing injury and total time loss as a result of injury. In particular, to observe any differences that may have occurred due to alterations to the comprehensive medical management programme employed, notably an extended screening and a novel intervention programme in addition to detailed injury surveillance data. The results indicate an overall decrease in injury incidence through the period of the study. There is a significant difference ($p<0.001$) in the overall incidence of injuries in Year 1 with that of Year 2. A smaller non-significant decrease in injury incidence was noted between Year 2 and Year 3. Female dancers displayed a significant decrease ($p<0.001$) in injury incidence between Year 1 and Year 2, but a slight increase in injury incidence between Year 2 and 3 from 1.7/1000hrs to 1.8/1000hrs. The increase in injury incidence between Year 2 and Year 3 was as the result of one more recorded injury. A similar pattern of decreasing injury incidence is noted with the male dancers with a significant reduction in injury incidence recorded between Year 1 and Year 2 ($p<0.001$). A smaller reduction in injury incidence was also noted between Year 2 and Year 3. The impact of this study was anticipated to be a positive effect on dancer's health and careers. The decrease in number and incidence of injuries suggest the value of this intervention to dancer's health. It was also anticipated that there would be a positive impact on the company who employ the dancers whereby more non-injured dancer time would be available. An overall reduction in days lost to injury suggests supports positive impact of this intervention from the Company's perspective.

5.4.1 Injury Surveillance

A significant reduction in injuries was noted between Year 1 and Year 2, with a further non-significant reduction noted in Year 3. Reductions in injuries have been demonstrated in other studies. In professional ballet Solomon et. al. (1999) reported decreases in injury numbers of 137 in the 1st year to 101 in the 5th year as a result of an injury audit system and employment of in-house medical provision. Similarly, decreases in injury incidence were reported in injury incidence in a professional modern dance company as the result of introducing in-house medical provision (Ojofeitimi and Bronner 2011). What is unique in this study is the significant reduction of injuries in a company that already used in-house medical provision proving greater support for the changes to the in-house medical system (screening and intervention programmes).

The overall mean severity in days decreased between Year 1 and Year 2. This reflects the decrease in severity reported by Ojofeitimi and Bronner (2011) who noted a 65% decrease in lost days. However, in this study Year 3's overall female mean severity was higher than Year 1 and Year 2. There are two potential reasons for this. Firstly, the presence of a few more serious injures noted in Year 3. Secondly, it may reflect the change in patient management where more time was afforded to certain injuries in a strategy to reduce recurrent injuries. This is reflected on by Orchard and Seward (2009) when commenting on an increase in severity of hamstring injuries in Australian Football League. When examining the overall decrease in days lost between Year 1 and Year 2 and Year 3, it continues to provide overwhelming support for the use of these intervention strategies in reducing the impact of injury in elite ballet.

The continued high incidence of less severe injuries, indicated by the fact that injuries that resulted in less than seven days absence accounted for 41% of the time loss within this study, supports the use of a more encompassing time loss injury definition to ensure that the more minor injuries are part of the overall accountability of the surveillance system and that intervention strategies are aimed at reducing all injuries sustained by the company.

5.4.2 Rank

As discussed in Chapter 3, the type of role a dancer may perform within a particular choreography can be largely related to the rank they hold within the company. The trend of decreasing injury incidence follows through all ranks in both male and female dancers between Year 1 and Year 2 and 3, with the exception of the male artists' category between Year 1 and Year 3. This remained the same and the male soloists recorded an increase in injury incidence. The reason for this increase may be due to the promotion of younger dancers into the soloist ranks undertaking "principal" and "solo" roles on stage in Year 2 and 3, as opposed to the high predominance of character dancers within the soloist rank in Year 1, where these solo type roles were undertaken by 1st artists.

Between Year 2 and Year 3, there appears a slight increase in injury incidences in all but the male and female principals who consistently showed a decrease in their injury incidences over the three years. A potential reason or the slight fluctuations in injury incidences between Year 2 and Year 3 may arise from the smaller number of injuries noted. The differences in incidences for female principals, soloists, 1st artists and artists are based on an injury number difference of a maximum of 3 injuries from a mean of 18 injuries per rank between Year 2 and Year 3. For the male 1st artists and artists, the difference in injury numbers was a maximum of 5, off a mean of 25 injuries per rank. The reduction of the injury incidence of the male principals between Year 2 and Year 3 may be associated with the retirement of one male principal; who in previous years had an above mean number of injuries compared with the other male principals. With the failure to recruit a replacement principal dancer, the workload for that dancer then moved onto the male soloist rank.

There was a reduction in severity across the female ranks between Year 1 and Year 2, but an increase in severity in principals, soloist and artists in Year 3. This trend follows the overall pattern of a slight increase in severity in Year 3 of the study for female dancers. Male dancers also recorded a decrease in the overall severity of all but the soloist rank in Year 1 and Year 2 and 3. The changes within the soloist rank, from predominately character dancers in Year 1 to some promotions of younger dancers in Year 2 and 3 may explain the increase in both incidence and severity of this group.

In Year 1 of the study, the female soloists and artists recorded injury incidences higher than the mean for females in that Year. In the next two years, only the female artists record injury incidences greater than the group mean for females. Amongst the male dancers, all but the male soloists recorded injury incidences greater than the group mean for males within that year. In Year 2 of the study, only the principals recorded an incidence rate higher than the group mean, whereas in Year 3, all but the male soloists recorded incidences greater than that of the group mean for that year. Principal dancers were the only group within the ranks to record a continual decrease in injury incidence throughout the study period. Artists continued to record higher incidences of injury compared with the mean incidence for their gender. A dancer's resilience to injury appears to be a combination of their skill and physical attributes. Artists are generally younger and physically less mature, and less technically skilled members of the company. As such, these dancers would have a lower resilience to injury than the older, more skilled members of the company. The injury incidences from this study suggests that as a group, the artists still represent a vulnerable group and could benefit from more concentrated efforts to improve injury incidences.

However, when examining risk across the female dancer's ranks, with the exception of the 1st Artists in Year 1, risk appears equal among the ranks; while in Year 2 Soloists demonstrate greater risk. In Year 3 risk appears higher in all but the 1st Artists. Male dancers however demonstrate higher risk to 1st Artists and Principals in Year 1 and 2, with the 1st Artists remaining the at risk group in Year 3. The difference of patterns in risk and injury incidence highlight the value of including exposure within injury data collection as it allows for more detailed risk assessment which can better serve to direct resource allocation.

Although no other study was found that reported the changes in injury incidence as a component of rank, Solomon et. al. (1999) does report a greater proportion of injuries in Corps dancers. However, the authors do comment on how the percentage of injuries are balanced in any group and the percentage of dancers represented in any given group, and the percentage of the total number of injuries experienced by members of that group, were very close. This demonstrates the limitations of the cross comparisons between the studies in this respect.

5.4.3 Activity

Class, rehearsal and performance incidences reduced for both genders between Year 1 and Year 2 of the study. Rehearsals consistently provide the lowest incidences of injuries to both female and male dancers through the three year period with class and performances recording much higher incidences. Female dancers reported an increase of 1.2/1000hrs in injury incidence between Year 2 and 3 from Performances, whilst male dancers recorded an increase of 1.3/1000hrs in injury incidences between Year 2 and 3 from Class. The severity of female injuries in class increased throughout the study as did the severity of male injuries during performances in Year 3. Again, due to smaller numbers recorded in Year 2 and Year 3, there is a limit to the power of relationships in each category. No studies were found that demonstrated changes in the various dance related activities to allow cross comparisons.

The exposure period for this study was limited to dance related activities due to the ability to calculate exposure. Although the prevalence of injuries outside of dance related activities was very low (these injuries were documented but excluded from the reporting of this study) expanding the exposure period to include all work related activities (including Pilates, rehabilitation, fitness and other conditioning work) will enhance our understanding of dance and account for the impact of the accumulation of loading on the body in the development of injuries through extended exposure.

The variations in the repertoire between the years may account for differences in the injury rate reported. There may also be some gender specific ramifications, for example some choreographies, like Swan Lake undertaken in Year 3, has a greater impact on the female dancers as a group than male dancers as a group. In order to assist in the overall reduction of injuries as well as the implications of severity on injury and reinjures more in depth work is needed to further ascertain the variable nature of the challenges of a varied repertoire, with particular attention to the impact on gender.

5.4.4 Episode

The reduction of recurrent injuries is an important step in reducing the overall incidence of injuries (Stasinopoulos 2004, Hägglund, et. al. 2006) as well as potentially addressing some aspects of the longer term sequelae of injury (Myklebust and Bahr 2005). The present study indicates that recurrent injuries decreased significantly throughout the three year period of this study ($p<0.001$).

Female dancers recorded increases in exacerbations through the three year study, with exacerbations in both Year 2 and 3 accounting for the highest incidence of injuries compared with first-episodes and recurrent injuries. Due to the small number of injuries in the Year 2 and

Year 3 aspect of this study, the power of outcomes in smaller categories needs to be taken into consideration. The increase in incidence is related to an increase in number of injuries by three between Year 2 and Year 3. The mean severity increased in Year 3 compared with both Year 1 and Year 2. This is related to the occurrence of one very severe injury already mentioned. Male dancers recorded a decrease in exacerbations through the three year period, but did report a slight increase in first episodes between Year 2 and Year 3.

As discussed in chapter 3, the nature of the in-house medical team, as a point of free and easy access for dancers, resulted in a number of dancers having treatment for a complaint that did not have an impact on dance related activity. An exacerbation was recorded when the complaint escalated into an injury and resulted in a partial (or full) withdrawal from dance related activity. The increase awareness of the clinical staff of the overall impact of dancers continuing with activities, while affected by a complaint, may have influenced the increase in first-episodes and decrease in exacerbations by advising dancers to consider reducing the amount or content of dance related activities in order to reduce the potential impact of injuries. The smaller numbers reported in Year 2 and 3 may diminish the power of those outcomes, but still provide a starting point for further analysis. Some increases in severity can be directly linked to the occurrence of one or two very severe injuries (as seen in Year 3) or the increase of a number of moderately severe injuries (as seen in Year 2).

5.4.5 Injury Causation and Type

In Meeuwissee's (1994) theoretical model looking at causation of injury it is suggested that it is the intrinsic factors that predispose the body to injury, but that intrinsic factors seldom lead to an injury alone. It is the combination of both intrinsic and extrinsic factors that can leave an athlete susceptible to injury.

In order to assess the impact of potential causation factors, injuries were classified as having an intrinsic or extrinsic causation. The results of Year 1 also indicate that intrinsic causation factors were a major influence in the injuries sustained within the company. As such, the main focus of the changes to the comprehensive medical management programme looked at reducing the risk of injury by minimising the risk from intrinsic factors, knowing that the interaction between the intrinsic and extrinsic factors should suggest that both would benefit from the intrinsically focussed intervention. Both intrinsic and extrinsically related injury incidences showed a statistically significant decrease between Year 1 and Year 2 ($p<0.001$), but there was a greater difference in injury incidence in between Year 1 and Year 2 for intrinsic injuries (female: 1.51/1000hrs; male: 2.95/1000hrs) than extrinsic injuries (female: 0.93/1000hrs; male: 0.90/1000hrs). There was a variability of incidences noted between Year 2 and Year 3 where female dancers recorded a slight increase in extrinsically related injuries and a decrease in intrinsically related injuries, while males recorded a decrease in extrinsically related injuries while intrinsic related injuries remained constant.

Although subject to interpretation and bias, the outcomes provide some support for the classification of injuries into intrinsic and extrinsic causation, as it can provide a useful means to understand injury causation better. It may also assist in providing the justification for interventional approaches, like the intrinsically focussed individual conditioning programmes in this study, that following implementation, has shown a good reduction in injuries within that classification, as well as through the interaction of intrinsic and extrinsic factors, impacted on the incidence of extrinsically related injuries as well.

With the recursive nature of injuries, the classification of overuse and traumatic injuries, and the subsequent calculation of severity for, in particular, overuse injuries is important. With a recursive model of injury, the presence of a single identifiable event may distract from the period of abusive training that predisposed that event, resulting in a greater number of traumatic injuries being classified than accurately occurred. Further research into mechanisms of injury, inciting events and biomechanical components of dance injury within this cohort may serve to improve the understanding of the risk factors of dance injuries in relation to the findings of this study.

With a change to the comprehensive medical management programme that was designed to target and improve intrinsic factors like muscle balance, stability and strength, it was expected to have an impact on the causation of injuries sustained. It has been suggested that neuromuscular training positively influences arthrogenic muscle inhibition, where muscles are inhibited from full activation due to previous injury (Tenforde et. al. 2012). This may support the changes noted due to neuromuscular training where plyometric exercise components have demonstrated changes in muscle power, strength and speed, while strength exercise components have demonstrated increased power to stabilize target joints (Yoo et. al. 2010). Atta (2012) suggests neuromuscular training is efficient in improving muscle strength, reaction time and balance. In addition, gains made in “core control” may help avoid serial distortion patterns that can influence injury. Exploring potential changes as a result of neuromuscular training, O’Driscoll and Delahunt (2011) indicate varying levels of support from randomised control trials for improvements in joint acuity, muscle reaction time and fatigue (using electromyography measures), and strength changes, following neuromuscular training. These findings serve to support the inclusion of neuromuscular training in this study and support the relationship between these changes and decreases in injury incidence observed.

It was also felt however, that with targeted improvements to intrinsically related risk factors, the incidence of overuse injuries may improve as well. Greater differences were noted in the reduction of overuse injuries compared ($p<0.001$) with that of the reduction of incidences of traumatic injuries ($p=0.025$). Female dancers recorded a decrease of 1.7/1000hrs between Year 1 and Year 2, (with a slight increase of 0.10/1000hrs between Year 2 and Year 3), but only a decrease of 0.6/1000hrs in traumatic injuries between Year 1 and Year 2 (and no difference between traumatic injuries between Year 2 and Year 3). Likewise, male dancers recorded larger decreases of 2.0/1000hrs in overuse injuries between Year 1 and 2 (and small decrease of 0.05/1000hrs between Year 2 and Year 3) than the decrease of 0.4/1000hrs in traumatic injuries (and 0.13/1000hrs between Year 2 and Year 3). Acknowledging the lower level of evidence from which this data is drawn, but weighing up of the harm versus benefit from the patient important outcome of injury prevention (Guyatt et. al. 2011), this would support a recommendation for the use of intrinsically focused intervention programmes for dance, particularly as the presence of higher occurrences of overuse injuries has been reported in the literature (Nilsson et. al. 2001, Bronner et. al. 2003).

5.4.6 Body and Injury Groupings

The small numbers of injuries in some classifications, like body and injury groupings, reduce any powerful analysis of the data. A cluster analysis was attempted, but failed to provide insight as to whether statistically supported relationships existed between various injury groupings. This study used a standardised injury diagnosis coding system, the OSICS, supported by weekly injury meetings to improve inter-testing reliability and validity. Inter-tester reliability research could be undertaken in regards to the diagnosis codes for the team using them. Further research could look at the validation of injury diagnosis. The validation of the body and injury groupings may also be questioned as, while they were based on the OSICS, were grouped according to the author's opinion regarding clinical relevance and the distribution of injuries within the study, to allow improved numbers for analysis.

Value may still, however, be gained in analysing this data to allow some appreciation of the trends and patterns of injuries and so provide potential support for specifics required for conditioning programmes and supporting the inclusion of interventional strategies. The injury data alone provides valuable information, which in conjunction with the screening data, provides the basis from which individualised conditioning programmes were designed as part of the intervention strategy. These include the understanding of more common presentations, like "Ankle instability or ligament sprain including sinus tarsi" or "Medial Tibial Stress Syndrome", or infrequent but potentially catastrophic injuries like "head and neck injuries" and "concussion".

Overall mean screening scores failed to improve over the study period. The reasons for this have been explained in Chapter 4. The value of the screening is the identification of key areas within the movement patterns that may contribute to the risk of re-injury. In doing so it provides the direction for the interventional conditioning programmes. The example of an interventional conditioning programme given in the method reports a dancer who recorded a history of two ankle sprains in Year 1, resulting in 24 days and 2 days loss respectively. Unsurprising, there was a poor score recorded from the left leg balance test, a factor that would certainly fit with a previous history of ankle sprains. The presence of a positive Mens test on the left alongside a persistently asymmetrical and poorer scoring of the left hip when under test, supported the premise that a more proximal source of the instability was a key factor for the lower balance scores for the left leg (Appendix 5). As a result a conditioning programme was designed that had as its primary focus to address the presence of muscular instability of the sacroiliac joint (Appendix 6). This was targeted using the first two exercises (exercises 1 and 2) in each session (session 1a and b) through the facilitation of neuromuscular firing patterns to activate correct firing of the posterior muscular sling which provides a stabilising function for the sacroiliac joint. This was then supported with core strength control, from surrounding gluteus muscles, to support the sacroiliac joint initially in isolation (in lying postures) and then under functional loads (using standing postures). When stability was achieved, these were then progressed to include a more proprioceptive component. The decision to delay the instigation of proprioceptive type exercises, which would be advocated for the prevention of recurrent ankle sprains (Zöch, Fialka-Moser, and Quittan 2003) was based on the testing results, where initially commencing with proprioceptive exercise would have resulted in the same patterns of compensation noted during the testing, potentially reducing the effectiveness of the intervention. The results of the injury audit indicated no further ankle injuries were recorded.

The high incidence of lower leg injuries and Medial Tibial Stress Syndrome (MTSS) among male and female dancers in Year 1, provided justification to develop a management strategy for reducing injury incidence within certain dancers individualised conditioning programmes. One of the potential causative factors linked with MTSS, is the presence of a pronated foot (Yates and White 2004, Sommer and Vallentyne 1995). Within dance, the pronated posture of the foot may be further exacerbated in dancers attempting to achieve greater turn out at the hip in the face of apparent restriction of the hips lateral rotation (Clippinger 2005). A potential reason for restricted hip rotation is due to the over-firing of the iliopsoas muscle in response to the failure of key core stability muscles of the lower lumbar region to cope with the loading it undertakes (Russell 1991).

As a result of the screening of the dancers, the relationship between the lumbar spine and foot posture was appreciated and as such the intervention programme focussed on creating stability proximally, within the lumbar and hip regions. The results of the next two years of the study indicate a decline in MTSS in both female and male dancers between Year 1 and Year 2 and 3.

There was also a decrease in lumbar region related injury incidences from Year 1 to Year 2 and 3.

A body region less commonly linked to injuries in dance is the cervical region. Grouping the injuries allowed for the unexpected higher incidence of injuries from the cervical region to be recognised. As a result of this a 4-way isometric neck stability programme was instigated for those individuals identified to be at risk of cervical region injuries. This was based on work done in elite level Rugby Union, where the incidence of neck injuries is far greater reporting an incidence of 6.4/1000 match player hours (Fuller et al. 2007), supported by research undertaken in cervical stability in arthritis (Hakkinen, Makinen, Ylinen, et. al. 2008). The results in both female and male dancer's cervical region injury incidences over the three years suggesting this is a worthwhile approach in managing neck related injuries in dance. In relation to most sporting or dance injury incidences, the reporting of an injury incidence of 0.04/1000hrs may be seen as an acceptable level of injury in relation to participation, but when the injury incidence relates to concussion, it may serve as a note to health service providers that the opportunity of more catastrophic injuries can exist in dance, and suitably trained health-care personal in emergency pre-hospital care is a pre-requisite.

5.4.7 Limitations

Some limitations are noted in this study. It is acknowledged that randomised controlled trials are considered the methodology of choice for examining the impact of interventions. However, a component of the action research approach undertaken in this study relates to the theory-practice gap in clinical practice, where practitioners, after identifying gaps in the traditional knowledge that cannot be explored through more accepted and more scientifically sound means such as randomised control trials, draw on their intuition and experience to generate findings that are meaningful and useful to the environment that they are in (Meyer 2000). This is particularly relevant in dance where there has been a distinct lack of research and evidence into the overall reduction of injury incidence. It is accepted that these observational studies have a role in determining the benefits and harms of medical interventions (Black 1996 in von Elm et.al. 2008) but that the quality of evidence established through observational studies is low (Guyatt et. al. 2011; Balshem et. al. 2010).

A further limitation is that this study compared results of changes between Year 1 and Year 2 and 3. It is possible that Year 1 could have been an anomaly in injury rates. An extended longitudinal study will strengthen evidence for the use of the comprehensive medical management programme employed. Additionally, the present study was subject to limitations including imprecision, author and publication bias (Guyatt et. al. 2011a, d).

In order to determine the structure and content of the individual intervention strategies for the dancers, a combination of the injury audit results and intrinsic risk factors was used. Intrinsic risk factors were determined via a screening process (FPS). Limitations from this aspect of the study can arise out of issues surrounding its validity and reliability. There was no intra-tester reliability studies performed and the validity for this test in determining intrinsic risk in dancers has not been established. The failure to document improvements in screening scores between the years due to the physiological decay through a 5 week holiday period, and down rating of scores due to increased awareness of risk thresholds, was unsubstantiated in this study. Further work needs to be undertaken with regular screening undertaken pre and post implementation of intervention programmes to enhance the understanding of the impact of this screening programme.

A critical component comes from the combination of injury audit data with screening outcomes to provide the information from which individualised intervention programmes are designed. However, the use of individualised intervention also introduces confounding variables, including adherence to the programmes. The injury audit information provides a global picture as to the extent of the injury problem, but also provides a valuable database in order to further analyse the injury history and patterns of individuals, in comparison to a cohort of dancers within the same exposure. This information is then used in combination with that of the screening results in order to relate the injury history with potential intrinsic risk factors in order to design an appropriate conditioning programme. The validity of outcomes from the injury surveillance system is dependent on the choice of methodology and design. The injury surveillance system used incorporated a prospective design with a time loss injury definition.

5.4.8 Translation into wider dance medicine practice

The injury audit methodology and data collection tool has been utilised to support further research projects (Wyon, Koutedakis, Wolman et.al. 2013; Hopper, Allen, Wyon et.al. 2014). In addition, the system has been adopted by a major international professional ballet company as well as vocational schools, and will form the basis of a national epidemiological study undertaken with Arthritis Research UK's Centre for Excellence in Sport, Exercise and Osteoarthritis.

5.5 Conclusion

The changes to the comprehensive medical management programme noted in this study was the implementation of individual conditioning programmes, based on the information gained via the injury audit and the FPS, and designed using the Hybrid Intervention Model. With a significant reduction in the incidence of injuries in this cohort of professional dancers, there is considerable support for its use for the reduction of injuries in professional ballet.

Chapter 6: Overall Discussion

6.1 Introduction

While there is indication that regular physical activity can have extensive health benefits, there is still a question as to whether those benefits outweigh the risk of injury and long-term disability, with a particular reference to high level athletes (Ljungqvist et. al. 2009). One of the potential reasons for an increase in musculoskeletal injuries later on in an athlete's life has been linked to previous injury whilst still an athlete (Bahr and Holme 2003, Lee et. al. 2001, Drawer and Fuller 2001), with similar concerns having been expressed in dance (Teitz and Kilcoyne 1998). The prevention of injuries in order to support these elite performers both during their careers, to assist in the attainment of athlete's objectives, as well as providing a quality of life after retirement from the sport forms part of the role of sports medicine and in-house medical teams. Injury prevention models have been described in the literature, including van Mechelen's (1992) Injury Prevention Model. The overall objective of this study was to document injury incidence and severity in professional ballet dancers over three years, including any changes as a result of modifications to their comprehensive medical management, as part of the injury prevention programme. The purpose of this chapter is to demonstrate, through the utilisation of van Mechelen's (1992) injury prevention model, the development and results of the injury prevention programme

6.2 Injury Prevention Model

Within the sports medicine literature a model for the prevention of injury has been described by van Mechelen et. al. (1992). This model comprises of four strategic stages: Step 1- establishing the extent of the injury problem (number, incidence, time trends**,** severity, and consequences including impairments, disabilities and costs); Step 2- establishing aetiology, risk factors and mechanisms of injuries; Step 3- introducing a preventive measure or programme; Step 4- assessing the effectiveness and cost effectiveness of the preventive action by repeating step 1. The adoption of van Mechelen's injury prevention model was considered an essential aspect within this project as it provided a means for establishing a process for the prevention of injuries in dance with evaluation of its effectiveness as part of the process. The transferable potential between sports and dance medicine was accepted due to the similar athletic needs of both disciplines. It was felt the specificity of dance would need to be addressed within the injury audit and screening tools where appropriate.

6.2.1 Injury Prevention Model (Step 1): The Extent of the Injury Problem (Chapter 1)

A critical component of van Mechelen's model arises from understanding the extent of the sports injury problem, through establishing its incidence and severity. Although this may appear as a fundamental aspect of injury prevention, the dearth of well-controlled epidemiological studies suggest that its implementation is not universal. A number of factors are identified that have influenced the value of epidemiological studies.

An important aspect in establishing the extent of the problem within the injury prevention model comes from the validity and reliability of the findings. These are influenced by methodological issues, including definitions of injury, severity and exposure (Finch 1997). In some athletic pursuits, like dance, where there may not be a strong history of epidemiological research, coupled with the challenge of fewer resources, there is potentially a greater need to draw comparisons to other sporting disciplines. A key factor in the design of an injury surveillance system is a clearly indicated definition of injury, as it has a major impact on the nature (and validity) of the data collected. Further impact on validity and reliability comes from the methodological considerations in reporting of injuries, exposure and denominator data, incidence and severity of injuries, the distribution, nature and coding of injuries, and sample size. This chapter highlighted both the challenges and the importance of a methodologically sound injury audit system to ensure the validity and reliability of data for analysis within van Mechelen's injury prevention model.

6.2.1.1 Injury Prevention Model (Step 1): The Extent of the Injury Problem in Dance (Chapter 2)

A starting point for understanding the extent of the injury problem in dance is through the literature. To date there has only been two systematic reviews published on musculoskeletal injury and pain in dancers (Hincapie et. al. 2008; Jacobs et. al. 2012). The conclusions of the reviewers were that the literature has many limitations but despite these limitations the authors indicate that there is evidence that musculoskeletal injury is an important issue for all dancers and that there is preliminary evidence that comprehensive injury prevention and management strategies may reduce injuries (Hincapie 2008). The follow-up review (Jacobs et. al. 2012) reiterated the need for explicit criteria on injury definition and methods of injury reporting and comment that there are still major scientific limitations and biases in the literature reviewed.

An up-to-date systematic review was conducted (Chapter 2) using the guidelines from the GRADE system (Guyatt et. al. 2011; Brozek et. al. 2009a), the AMSTAR tool (Shea 2007) and the PRISMA statement (Moher 2009) to determine the level of evidence (and confidence) around musculoskeletal injury rates and pain in dancers and the potential impact that comprehensive medical management may have on overall injury rate and pain. The results of the systematic review performed in Chapter 2 using the GRADE system were similar to the previous published reviews by Hincapie et. al. 2008 and Jacobs et. al. 2012 in that a low level of evidence was noted. Using the GRADE system two patient important outcomes, namely INJURY RATE and INJURY REDUCTION were examined across the studies retrieved and an overall rating of evidence for both outcomes was very low due to a down-rating of the evidence due to serious limitations, inconsistencies and in respect to INJURY REDUCTION also imprecision. A notable aspect of GRADE is that the direction and strength of recommendations may differ from the evidence profile if the proposed benefits outweigh any harm. The use of the Evidence to Recommendation Framework enhances the transparency of those recommendations. A strong recommendation for the use of comprehensive medical management for the reduction of injury rate in dancers is advocated in the absence of stronger evidence. This recommendation contained the two publications taken from this thesis, namely Allen et. al. (2012), and Allen et. al. (2013). It confirms that in environments that RCT's are not an available means to test intervention, research using observational methodologies can still provide important information to stakeholders.

6.2.1.2 Injury Prevention Model (Step 1): The Extent of the Injury Problem in Dance, a Prospective Cohort Study (Chapter 3)

In determining the extent of the injury problem within this particular cohort, it was important to obtain valid and reliable results, as well as to allow some aspects of cross-study comparisons to both sport and dance to take place. As already discussed, issues surrounding varying injury definitions and methodological flaws have meant that the impact of injury in dance is poorly understood. Furthermore, the use of observational studies produces lower levels of evidence. The use of the STROBE statement for guidelines for reporting of observational studies can improve the strength of the outcomes observed. As such a prospective cohort study was designed and implemented to allow better validity and reliability of reported injuries than those seen in retrospective dance studies (Brinson and Dick 1996, Laws 2005, Chmelar et. al. 1987, Sohl and Bowling 1990, Bowling 1989, Ramal and Moritz 1994, Evans et. al. 1996, Gamboa et. al. 2008). The nature of this design also allowed non-injured dancers and exposure to be included in the analysis. The further value of including non-injured dancers in the analysis in this study was noted when exploring the potential intrinsic risk factors, as it allows for a comparison between injured and non-injuries dancers to help determine the clinical relevance of potential intrinsic risk factors. Exposure was recorded using call sheets and performance schedules. An all-encompassing time loss injury definition was used where injuries were recorded if they resulted in full or partial withdrawal from scheduled dance related activity sessions. The advantage of this injury definition is that it allows cross-comparison with other major epidemiological research papers across a number of professional sports. In the absence of any comparable dance papers it therefore allowed an initial understanding of the more apparent minor injuries that do not require full withdrawal from dance related activities. Accounting for these apparent minor injuries can have a positive impact on both preventing the development of more severe injuries as well as potentially long-term pathological changes due to a long term sequelae of injury. Despite being the most commonly used injury definition for many sports, a question has been raised over the use of a time loss injury definition in (sporting) population groups where overuse injuries are anticipated (Bahr, 2009). Bahr (2009) indicates that the onset of pain can precede the point at which removal from training occurs in overuse injuries, misleading clinicians as to the full impact of these injuries as the usual time loss injury definition does not account for the period before full withdrawal from activities is noted. Within this study, the use of a partial and full restriction of dance related activity was used as the injury definition. The benefit of this delineation of the time loss injury definition is that injuries that may be within the painful stage but not resulting in full withdrawal from exposure related activities are still registered if they impact of the dancer being able to complete all of their requirements, a distinct possibility in a patient with an underlying overuse injury. As such, dancers with underlying overuse injuries were potentially recorded through for example by their partial withdrawal where they would tend to hold back from “full jumps”, but were still technically completing their required workload. Severity in days was calculated using the date of return to full dance related activity minus the date of injury onset. Calculating the severity of injuries is crucial in understanding the extent of the injury problem. The inclusion of exposure data also allowed risk to be calculated in respect to amount of days lost as a component of dance per 1000hrs. The occurrence of injuries was recorded to give a greater understanding of where the focus of an intervention strategy may lie. A higher incidence of first episodes may be reflected in a strategy aimed at preventing injuries, whereas a high incidence of recurrent injuries may question the management of those injuries and the decision as to when patients are allowed return to full activities. Similarly high incidences of exacerbations may call into question the management of patients in relation to what level of participation to dance related exposure should be allowed. The incidence and severity was recorded for the various ranks in order to determine if one particular group would be identified as “at risk” and warrant a more detailed approach to injury prevention, for example, younger and more inexperienced dancers needing extra conditioning to cope with the rigors of professional dancing, or those dancers moving up the ranks needing to accommodate to the increases in intensity and technical requirements (complex jumps, lifts etc.) of roles performed (Twitchett et. al. 2009). The activity performed in sustaining the injury was also documented to reflect the impact of workload type on injuries sustained. Details of the body region and injury groupings were also recorded. In recognising the sequencing of injury prevention, capturing data that may inform and influence the intervention strategy was important, as such understanding issues surrounding the nature of injury causation (intrinsic or extrinsic causes), as well as the type of injury (overuse and traumatic), the impact of injury prevention strategies may be improved. Although both the nature of injury causation and type of injury will be a subjective, based on the clinicians experience and interpretation, the risk-benefit analysis would suggest that at best it would help steer the direction of an intervention strategy, and at worst, it would do no harm, and as such, is worth exploring. The results would need to be taken in context of its reliability and sensitivity, and as part of a more global picture created through the rest of the data collected. To improve inter-tester reliability when recording specific details on injuries sustained, the OSICS was employed. In collecting body and injury specific data, interventional strategies can be more focussed on the needs of the cohort in question. Although challenged in research terms by the expected small numbers within the various groupings, the value of body and injury groupings from a clinical perspective is great and allows the accountability side of clinically based research projects to be satisfied.

An overall incidence of 4.44/1000hrs dance was recorded, with similar injury incidences noted between female (4.14/1000hrs dance) and male dancers (4.76/1000hrs dance). This is within the upper limit of injury incidences reported in ballet (0.62-5.6/1000hrs)(Gamboa et. al. 2008, Luke et. al. 2002, Nilsson et. al. 2001 Leanderson et. al. 2011), although the wide variety of injury definitions used including medical attention (Nilsson et. al. 2001, Gamboa et. al. 2008, Leanderson et. al. 2011) and methodological deficiencies including retrospective study (Leanderson et. al. 2011 Gamboa et. al. 2008), as well as the heterogeneity of the studies, including being based on student participants (Luke et.al 2002, Leanderson et. al. 2011), affect the validity of comparisons. By using a comparable injury definition and methodology, comparisons with other sports based epidemiological studies was made. The current cohort of professional ballet dancers experienced a much lower incidence of injury than has been reported in many competitive contact sports such as rugby union (17/1000hrs:Brooks et. al. 2005) and soccer (8.5/1000hrs:Hawkins and Fuller 1999) or artistic sport like gymnastics (overall incidence of 22.7/1000hrs) but higher than in elite volleyball (1.7/1000hrs) (Bahr and Bahr 1997). Professional ballet dancers in this study perform many more hours of practice and performance per week than professional athletes in many other competitive sports (Brooks et. al., 2005a,b; Hawkins and Fuller 1999). Consequently, despite the disparity in the incidence figures, dancers still received an average of 6.8 injuries per year, more than the 0.88 injuries per year per players reported in football (Hawkins and Fuller, 1999) or 0.90 injuries per player per season in rugby (Brooks et. al., 2005a,b). Whether driven from the medical perspective of ensuring the health and well being of dancer in both the short and long term, or the dancers perspective of being able to perform without limitation, or even the business perspective of potentially the financial cost behind injuries, the fact the an injury incidence of 4.4/1000hrs in

Year 1 was recorded confirmed the need for the reconsideration of the comprehensive medical management programme in place at this professional company.

There is sometimes an omission in reporting the severity of injuries within dance studies. The severity of injuries in this study was noteworthy. There was an overall average severity of 6.8 days in Year 1 of the study. Gender differences were evident with the average severity of injuries to male dancers (9 days) more than twice that of the female dancers (4 days). While the highest incidence of injury was as a result of class, with males recording a higher average severity during class, female dancers recorded higher average severity during performances. Despite a similar overall incidence of injury between the genders, the position held by a dancer in the company appears to relate to injury incidences differently according to gender. Female artists and soloists recorded the highest injury incidence and average severity, while male 1st artists and principals recorded the highest injury incidence and average severity. Further exploration into the type of injury noted that both male and female dancers saw a majority of injuries being classified as overuse injuries. This is consistent with findings in other studies in dance (Bronner et. al. 2003; Luke et. al. 2000; Nilsson et. al. 2001; Shah 2008; Solomon et. al. 1995; Solomon et. al. 1999). This may be unsurprising with the extensive exposure periods experienced by the dancers, coupled with the repetitive nature of some aspects of the dancers' workload (Ureña 2004). This, in combination with the majority of injuries for both genders being linked to potential intrinsic causes, provides support, albeit it from low level evidence, for implementing an intrinsically focussed intervention programme.

The specific data collected around body and injury groupings confirmed findings of previous studies that the foot and ankle, knee and lumbar regions are at risk of injury in dance (Gamboa et al. 2008, Garrick and Requa 1993, Milan 1994, Nilsson et al. 2001, Solomon et al. 1999, Prisk, O'Loughlin, and Kennedy 2008, Russell, Shave, Yoshioka, et al. 2010, Wiesler, Hunter, Martin, et. al. 1996, Macintyre and Joy 2000, Milan 1994). Some gender differences were noted with males experiencing more lumbar muscle strains and thoracic joint pathologies and females experiencing higher incidences of foot muscle and 1st metatarsalphalangeal injuries. Further reasearch could investigate the mechanism related to these injury presentations, looking at, for example, the role of lifting in male dancers and going en pointe in female dancers and relating them to the gender specific injuries seen. While the numbers reported in the injury categories were relatively small, the use of specific body and injury groupings also provided the basis for uncovering more unexpected injuries with higher than average incidences, for example the cervical region injuries in female dancers in this study. It also served to identify where even with low incidences, attention should be paid to the presence of certain injuries due to their longer term consequence (anterior cruciate ligament rupture) or specific training needs for those health care professionals associated with dance companies, like the management of head injuries and concussion.

A severe lack of well controlled and methodologically consistent injury epidemiology studies of ballet dancers restricting the ability to understand fully the aetiology and risk factors to this population of athletes has already been identified (Liederbach and Richardson, 2007; Hincapie et. al., 2008; Gamboa et. al., 2008). Some of the methodological procedures and epidemiological study issues within dance have already been outlined (Bronner et. al., 2007), however, there is a pressing need within the dance medicine community to standardise methodological procedures used in injury epidemiological studies via international consensus, a matter reflected by Liederbach and Richardson, (2007) and something that has been achieved in other sports (Fuller et. al., 2006; Fuller et. al. 2007; Pluim, et. al. 2009). This prospective single cohort study of professional dancers used a time-loss injury definition that in the absence of an international consensus statement of injury data collection in dance is consistent with the three international consensus statements in sports. An overall rate of 4.4/1000hrs was reported. The rate of injury in this cohort of professional ballet dancers was higher than others reported in ballet but low in comparison with many other sports. A need to introduce interventions to reduce the risk of injury was identified due to the high number of injuries reported and absence caused during the study.

6.2.2 Injury Prevention Model (Step 2 (Step 2a), and 3): Establishing Aetiology, Risk Factors and Mechanisms of Injuries and Introducing a Preventive Measure or Programme (Chapter 4)

Meeuwisse (1994) indicates that understanding the cause of injury is central to advancing knowledge in prevention and management of injuries while Fuller and Drawer (2004) define a risk factor as “a condition, object or situation that may be a potential source of harm to people” and risk as “the probability or likelihood that a risk factor will have an impact on these people”. Risk factors can be categorised as intrinsic or extrinsic (Fuller and Drawer, 2004, Bahr and Holme, 2003, van Mechelen et.al., 1992, Meeuwisse 1991). Intrinsic factors are considered to be those specific to an individual participant, and can include age, strength and joint stability, whereas extrinsic factors arise from external sources, and would include surfaces, protective equipment and laws of the game (Fuller and Drawer, 2004). Meeuwisse (1994) suggests that it is the intrinsic factors that predispose to injury, but they seldom lead to an injury alone, and it is the combination of both intrinsic and extrinsic factors that can leave an athlete susceptible to injury and that “an inciting event” provides the final variable in the injury causation model. The results of epidemiological study (chapter 3) suggest that injuries may be more intrinsically focussed in this cohort. The decision to apply a delineation of step 2 of van Mechelen’s injury prevention model by the in-house medical team was therefore reflective of the need to enhance the understanding of intrinsic risk factors.

In the delineation of the injury prevention model the expansion of step 2 included the extension of the pre-season/pre-participation screen (step 2a) (chapter 4). This would provide the in-house medical team with the means for establishing potential intrinsic risk factors. This data was then used in conjunction with the information gained in step 1 and 2 to introduce a preventative measure or programme (step 3). The process proposed in step 2a used to capture these factors took the form of an extension of their pre-season screening process called the Functional Performance Screen. The use of pre-season or pre-participation screening is not new in sport or dance. Used in general populations to provide indications of possible pathologies, its use in sport and dance has been to prevent injury and advance performance. However like injury surveillance, issues over validity and reliability and consensus over which process should be used are raised. Screening has taken the form of musculoskeletal testing, sport specific testing or combinations of the two. There has also been the advent of “functional” screening protocols designed to capture the movement patterns governing the quality (or compensation) of normal movements. The results for screening protocols in the literature to date are mixed. The ability for some musculoskeletal tests to predict injury has been proposed (Bradley and Portas 2007), with the reliability of certain musculoskeletal tests providing a suitable degree of intra and inter-tester reliability Gabbe, et. al. (2004). Similarly, one functional screen (FMS) has show to have some predictive value in a particular sport or activity (Chorba, et. al. 2010 O'Conner, et. al. 2011, Kiesel, et al., 2007, Peate, et. al. 2007), as well as acceptable inter-tester reliability (Minick, et al., 2010, Onate et. al. 2012, Teyhen, et. al. 2012). Within dance Schon, et. al. (1994) and Southwick and Cassella, (2002) indicate the results of a screening process that incorporates musculoskeletal aspects as well as dance specific has led to correction of identified problems, while Southwick and Cassella, (2002) reports improvement in key muscle groups as part of the Boston Ballet Student Screening Clinic using musculoskeletal and dance specific screening techniques. Although Gamboa et. al. (2008) demonstrated a significant difference in the prevalence of foot pronation (on the right) and lower extremity strength in their injured group versus the uninjured group they conclude that very few differences were found between injured and non-injured dancers and questioned the utility of broad-based screening programmes to predict, prevent or manage injuries in dancers. This is contrary to the findings of Bronner et. al. (2003) who demonstrated a reduction of injuries in a modern dance company in a "comprehensive medical management" approach that included screening. No studies were found utilising a normal movement screen in dance or ballet.

The approach for the FPS used in this study subscribed to the "regional interdependence" within the body, where dysfunction in one aspect of the body may contribute to weakness, tightness or pain in another aspect of the body (Wainner et. al. 2007, Minick et. al. 2010). The FPS used the results of a functional movement screen to determine the site of the segmental deficiency in relation to the movement patterns and performance. The interpretation of the results of the testing was not taken as an exponent of, for example muscle power or length, but as part of a summation of the ability of the kinetic chain to accept and cope with the loading during the athletic performance. By using the information gained the source of the dysfunction could be identified. This information was then combined with the results of the injury audit to allow an appreciation as to the intrinsic risk factors in relation to an individual's own injury history as well as in relation to the rest of the cohort undergoing the same exposure. This then provided the foundation for the creation of individual intervention programmes for dancers based on their own identified intrinsic deficiencies and areas for performance contributions.

Some studies have explored the predictive nature of screening for injury prevention. The rationale behind the design of the FPS was not directed towards the overall predictive nature of injury, but more the practical information gained to assist in the design of conditioning plans to directly influence intrinsic risk factors. The regional interdependence of body segments within this model may occlude the predictive ability due to the intricate and multi-factorial interactions of body segments and their response to biomechanical loading.

The design of the interventional programmes was a result of reflecting on the evidence available in the literature, the initial outcomes observed within the early stages of the study and the experience of the in-house medical team in elite level performance. Through the Hybrid Intervention Model the individual intervention programmes were designed. The process of facilitating neuromuscular control and motor firing patterns provided the first phase for the individual conditioning programmes. With varying success rates noted in the literature for the management of pathology with exercise, it was reflected that the first phase was a crucial in providing the "stable platform" from which more traditional exercises like strength and functional based exercises would be dependent. It was felt that without this the outcomes maybe less optimal and potential detrimental as the risk of concomitant injury may be increased as loading would have been advocated without appropriate local and global stability. The second phase of the conditioning plan was designed to utilise the creation of the local stability and to address any issues of local deficiency to provide support for the key local stabiliser, ensuring the resilience to increased or higher threshold loading associated with dance. The third phase was designed to allow an integration of the first two phases into a more functional based posture, normally as a weight bearing/ standing based exercise, with movement/biomechanical links to balletic requirements. By proposing a conditioning programme that was linked to tests to determine the state of neuromuscular control of key regions like the lumbar pelvic region, it was reflected that the progression through the phases and on to further conditioning programmes was both safe and efficient as well as indicated. The use of the determination of the "limiting factor" as being either the injury/deficit, cause or objective, gave further emphasis as to the construction of the intervention programme and influenced the relative ratios of the fundamental components of the programme.

6.2.3 Injury Prevention Model: Assessing the Effectiveness and Cost Effectiveness of the Preventive Action (Step 4 and Step 4a) (Chapter 4 and 5)

It is recognised that the building of a knowledge base can guide decision makers and research groups and clinicians into the management of common, severe or increasing injuries (Orchard & Seward 2009) which leads to more effective management of relevant injuries. On-going surveillance can both inform and test the implementation of these strategies (Parkkari, et al., 2001). A randomised control trial would be considered the gold standard for an intervention study (Schulz et. al. 2010) but was not used within this study due to the challenge of its implementation within a working professional company, where the exclusion of an interventional programme that may be of benefit was withheld in the control group, was not deemed acceptable to the management of the ballet company. In lieu of the implementation of a randomised control trial, this study employed the value of identifying problems within clinical practice and developing potential solutions through the qualitative approach in action research. Recognising the low level of evidence generated through the use of an observational methodology, the effectiveness of the changes to the comprehensive medical management programme as a form of intervention was described in two parts as part of the delineation of van Mechelen's model. Evaluating changes in the intrinsic risk as determined by the FPS could be useful in determining the impact that the intervention programme has made on those identified intrinsic risk factors (Step 4a). The second means falls within the original van Mechelen's model, where the repeating of the injury audit is used to determine the impact on injury incidence (Step 4).

Within this study, the ability to assess changes to intrinsic risk factors determined by the screening process is undermined by a number of methodological flaws including a failure to examine the inter-tester reliability of this screen or test its validity within this population group as well as changes in the screening content between Year 1 and Year 2 and 3. In reporting screening scores for Year 1 and Year 2 and Year 3, no improvements were noted. The reason explored for this related to the findings in the literature from sport relating to the decay noted in certain skills and physiological variables as a result of periods of cessation from training, as noted with the dancers in this study subject to a five week period of cessation of dance related activities. The reduction in mean screening scores between Year 1, Year 2 and Year 3 was attributed to the tester down-rating scores based on an increased awareness of certain injury presentation from the injury audit and the potential movement patterns associated with them. The reasons offered is not substantiated or tested further in this study. It was therefore necessary to utilise the re-auditing of injuries as per van Mechelen's step 4 in order to ascertain if changes to the comprehensive medical management programme resulted in changes in injury incidence in this cohort of dancers. The evaluation was based on the results of further two year injury surveillance. The years studied followed on consecutively from the first year studied. The injury definitions and methodologies remained unchanged, as did the medical team undertaking the injury data collection.

The results indicate an overall decrease in injury incidence through the period of the study. There was a significant difference ($p<0.001$) in the overall incidence of injuries in Year 1 with that of Year 2, and a smaller non-significant difference noted between Year 2 and Year 3. The number of days lost per 1000hrs decreased between Year 1 and Year 2, and there were some increases noted in average severity of injuries. In particular, increases in the overall severity of female dancers in Year 3 compared with Year 2. In response to the ongoing evaluation of findings within the injury audit, it is possible that more attention was paid to the impact of recurrent injuries and the role of extended tissue healing in the recurrence of certain injuries. As such, more time was afforded to those injuries increasing the apparent severity of the injuries reported. This is not directly substantiated but may be supported by a noted decrease in recurrent injuries throughout the study period to both genders. The influence of gender and role within the company still appears variable. While a general decrease in injury incidence when comparing Year 1 with Year 2 and 3 was recorded, the fluctuations of some ranks, like male soloists, would warrant further investigation. Similarly, the variability of incidence and severity in the various dance related activities would benefit from further attention.

The identification of causation factors in Year 1 suggested that intrinsically related factors may play a greater role in injury in this cohort. Meeuwisse (1994) suggested that it is the intrinsic factors that predispose to injury, but that intrinsic factors seldom lead to an injury alone, and it is the combination of both intrinsic and extrinsic factors that can leave an athlete susceptible to injury. Both intrinsic and extrinsically related injury incidences showed a decrease between

Year 1 and Year 2 and 3, but there was a greater difference in injury incidence in between Year 1 and Year 2 and 3 for intrinsic injuries (1.4/1000hrs and 1.6/1000hrs) than extrinsic injuries (0.9/1000hrs and 0.9/1000 or 0.8/1000hrs) for both male and female dancers respectively, with a decrease in severity noted (with the exception of female intrinsic injuries in Year 3) in both intrinsic and extrinsic injuries. Acknowledging the low level of evidence providing the data this would support the premise that there is an interaction between the intrinsic and extrinsic causation factors. Greater differences noted in the reduction of overuse injuries compared with that of the reduction of incidences of traumatic injuries over the three years supported the premise of the changes occurred as a result of an intervention programme designed to improve factors like muscle balance, strength and stability.

It is important to note that although the use of body and injury groupings results in small numbers being recorded within categories, by examining the incidence of injuries using body and injury groupings a more focussed representation of injury patterns within elite level dance to be started. This may lead to the understanding of more common presentations, like Medial Tibial Stress Syndrome, or infrequent but potentially catastrophic injuries like head and neck injuries and concussion. Using the results of chapter 3, further exploration into the aetiology of MTSS, in combination with the results of the FPS, lead the in-house medical team to the implementation of specific conditioning programmes focussing around the relationship between foot posture, the hip and lumbar region. The results of the next two years of the study indicate a decline in MTSS in both female and male dancers between Year 1 and Year 2 and 3 as well as a decrease in lumbar region related injury incidences from Year 1 to Year 2 and 3. A similar improvement in specific injury site incidence was noted with the implementation of an intervention specifically designed for cervical based injuries. Again limitations in the methodology and in particular the imprecision through small subject numbers needs to be taken into consideration but if benefits for the implementation of these strategies outweigh the harms, a recommendation for their use in professional ballet companies could be made.

Although explainable within the literature, with a failure to demonstrate the ability of the FPS to predict injuries, along with the failure to note improvements between screening scores from Year 2 and Year 3 and changes to the screening protocol made between Year 1 and Year 2 and

3, questions over the validity of the FPS still remain. By using a recognised injury prevention model it has allowed the complex and multi-factorial nature of injury causation and prevention to be evaluated from a low level of evidence perspective with a simple process of repeated measures via injury auditing. With the consistencies of the injury audit tool with international consensus statements on injury data collection and use of the STROBE statement guidelines reporting observational studies (von Elm et. al. 2008) the evidence is strengthened. A major reason for the undertaking of research is to inform clinical practice. The use of the GRADE system for the direction and strength of recommendations indicated that there is a strong recommendation for the use of comprehensive medical management programmes in the reduction of injuries in professional ballet.

Through using the four stages of van Mechelen's injury prevention model, this study confirms the value of a comprehensive medical management programme, consisting of individual conditioning programmes designed using data from an extended screening programme and injury surveillance data, in reducing the incidence of injury in elite level dancers through the observation of a significant reduction of injuries within this cohort of dancers.

Chapter 7: Conclusion

The presence of injuries in the exercising population has led to the development of sports and dance medicine, as well as the advancement of treatment techniques. But with potential longer term prospects of secondary pathological changes as a result of previous injury, there is a need to address the incidence of injuries through injury prevention and form part of the responsibility of those charged with caring for athletes like in-house medical teams for a professional ballet company. The overall objective of this single cohort observational study was to document injury incidence and severity in professional ballet dancers over three years, including any changes as a result of modifications to the comprehensive medical management, as part of an injury prevention programme. The results of the first year's study indicated an overall injury incidence of 4.4/1000hrs dance. This figure was higher than incidences reported in other ballet studies. The null hypothesis for Year 1 was that there would be no significant differences noted in respect to gender, rank, injury episode or type. The findings supported the null hypothesis in regards to gender but rejected the null hypothesis in respect of rank, injury episode and type.

Acknowledging the incidence and time loss as a result of injury, an intervention strategy was implemented by the in-house medical team through changes to the comprehensive medical management programme. The Functional Performance Screen used the premise of segmental deficiencies and evaluation of motor patterns and asymmetries as sufficient measure for understanding intrinsic risk factors in dance. The null hypothesis was that there would be no significant differences noted in respect to screening scores as a result of the comprehensive medical management programme. When analysing the results of the screening between Year 1 and Year 2 and 3, a significant decrease in mean FMS scores was noted between Year 1 and Year 2 with a further non-significant decrease in Year 3. The reason for this may be related to the decay in gains made through the instigation of the intervention programmes due to the 5 week cessation period because of the dancers scheduled summer holiday period and the down-rating of scores due to an increased awareness of injury patterns from the injury audit. The Hybrid Intervention Model was designed to optimise injury reduction through combining the key performance attributes noted in dance and sports in achieving a combination of movement efficiency and strength. The null hypothesis was that there would be no significant differences noted in overall injury incidence as a result of the changes to the comprehensive medical management programme. Furthermore there would be no significant changes noted in respect to gender, rank, injury episode or type as result of the changes to the comprehensive medical management programme. Through the instigation of individual conditioning programmes that followed a specified three phase approach (of initially improving neuromuscular control and motor firing patterns, then isolating and improving local deficiencies with the final progression to functional integration) the results demonstrated a 48% decrease in injury incidence between Year 1 and Year 2. These significant reductions were recorded in regards to gender, rank, injury episode and type, thereby rejecting the null hypothesis. This significant ($p<0.001$) decrease was maintained and improved on between Year 2 and Year 3 where a further 5% reduction was recorded. There was an improvement of 805 days in the total severity between Year 1 and Year 2, and although this increased then between Year 2 and Year 3 by 357 days, the reduction in recurrent injuries, suggesting that clinicians may be affording injuries the more time and clinical management to prevent their recurrence.

The objective of this study was to observe injury incidence and severity in a professional ballet company over three years. By rejecting the overall null hypothesis that there would be no significant changes to the overall injury incidence as a result of changes to the comprehensive medical management programme, this study confirms the value of a comprehensive medical management programme (consisting of individual conditioning programmes designed using data from an extended screening programme and injury surveillance data), in reducing the incidence of injury in elite level ballet dancers through the observation of a significant reduction of injuries within this cohort of dancers.

Chapter 8: Limitations and Further Research

The objective of this study was to utilise an observational methodology to report incidence and severity of injuries to a professional dance company over three years, including any changes in incidence as a result of changes made to the comprehensive medical management programme. This chapter will focus on limitations associated with observational studies and then the limitations associated with studies in general and identify where limitations in this study may fall and where future research may enhance our understanding further.

Prior to that one further serious limitation needs to be identified. Within this study the lead researcher also holds the position of Clinical Director of the professional ballet company studied. As such he initiated the research study, was instrumental in deciding both the nature of the study design and methodology, as well as involved in the injury data collection and analysis. Further to this he designed the changes to the comprehensive medical management programme. Throughout the research process, where possible, means to mitigate bias were employed through the use of the STROBE statement for guidelines for reporting observational studies and creating forums with fellow researchers/supervisors from the study and the clinical team involved so that opinion was balanced but findings and outcomes still need to be considered in light of this limitation.

With observational studies four key limitations are acknowledged (Guyatt et. al. 2011)

1. Failure to develop and apply appropriate eligibility criteria (inclusion of control population). Under- or overmatching in case-control studies. Selection of exposed and unexposed in cohort studies from different populations.

    - *In this study there was a failure to use any control group. With some cohort studies there is an option to use internal controls from participants not undergoing the intervention. This was not possible in this study as the Ballet Company management would not sanction a control group that did not receive intervention and as such the evidence obtained from the findings was* *downgraded from low to very low. Future research could look to employ internal controls to strengthen the evidence of the findings.*

2. Flawed measurement of both exposure and outcome. Differences in measurement of exposure (e.g. recall bias in case-control studies). Differential surveillance for outcome in exposed and unexposed cohort studies
   - *This study employed the use of estimated exposure. Although accepted in the dance medicine literature due to the difficulty in calculating full individual exposure, this needs to be acknowledge as a limitation to findings. Future research needs to explore better methods for calculating individual exposure.*
   - *The exposure period for this study was limited to dance related activities due to the ability to calculate exposure. Although the prevalence of injuries outside of dance related activities was very low (these injuries were documented but excluded from the reporting of this study) expanding the exposure period to include all work related activities (including Pilates, rehabilitation, fitness and other conditioning work) will enhance our understanding of dance and account for the impact of the accumulation of loading on the body in the development of injuries through extended exposure.*

3. Failure to adequately control confounding variables. Failure of accurate measurement of all prognostic factors. Failure to match for prognostic factors and/or lack of adjustment in statistical analysis.

   - *Various confounding variables were noted in this study. For example changes in repertoire and workload may account for differences in the injury rate reported. The use of an individualised intervention also introduces confounding variables, including adherence to the programmes. The control of confounding variables can be achieved through controlled studies and as such, the use of RCT needs to* *be considered if stronger evidence is sought for the efficacy of the comprehensive medical management programme in reducing injury rates in this cohort of professional ballet dancers.*

- *This study employed a time loss injury definition. The use of an all encompassing time loss definition may affect the reliability of injury reporting due to its expansive nature in comparisons to injury definitions that classify injuries solely due to match or performances missed. However this injury definition may still fail to account for those injuries that could have a role in the development of further injury but at that stage not restrict a dancer's performance capacity and as such not be classified as an injury according to the definitions set in this study. Further research could look to employ the spectrum of injury definitions proposed in the various international consensus statements on injury surveillance in sports, along with the prevalence of injuries, and provide an analysis as to which definition would provide the greatest degree of validity and reliability for this particular cohort and contribute to understanding the use of injury definitions in the dance environment in general.*
- *The issue over accurate reporting of injuries may also be raised. In a competitive environment, where dancers may feel the known presence of injury may adversely affect their career progression, the full reporting of injuries may not be accurate. Similarly, the documentation of injuries may be affected by staff time availability, particularly within the touring environment where staffing levels are lower, resulting in an increase in workload. Further research may look to explore a more sensitive measure for determining dancers who may have affected performance through the use of biochemical markers, providing an element of objectivity of the injury definition used.*
- *This study used a standardised injury diagnosis coding system, the OSICS, supported by weekly injury meetings to improve inter-testing reliability and validity. Inter-tester reliability research could*

undertaken in regards to the diagnosis codes for the team using them. Further research could look at the validation of injury diagnosis. The validation of the body and injury groupings may also be questioned as, while they were based on the OSICS, were grouped according to the author's opinion regarding clinical relevance and the distribution of injuries within the study, to allow improved numbers for analysis.

- *The recursive nature of injuries indicates there may not always be a sequential time line from a beginning to the end point for an injury. This is a limitation in the classification of severity where the calculation for severity is based on the date for returning to full activities minus the injury onset date. It would suggest from this model that the severity may be greater than calculated in this study. The impact would also relate to the classification of overuse and traumatic injuries and the subsequent calculation of severity for in particular overuse injuries. With a recursive model of injury, the presence of a single identifiable event may distract from the period of abusive training that predisposed that event, resulting in a greater number of traumatic injuries being classified than accurately occurred. Further research into mechanisms of injury, inciting events and biomechanical components of dance injury within this cohort may serve to improve the understanding of the risk factors of dance injuries in relation to the findings of this study.*
- *In order to determine the structure and content of the individual intervention strategies for the dancers a combination of the injury audit results and intrinsic risk factors was used. Intrinsic risk factors were determined via a screening process called the Functional Performance Screen. Limitations from this aspect of the study can arise out of issues surrounding its validity and reliability. There was no intra-tester reliability studies performed and the validity for this test in determining intrinsic risk in dancers has not been validated.*
- *The failure to document changes in screening scores between the years due to the physiological decay through a 5 week*

holiday period was unsubstantiated in this study. Further work needs to be undertaken with regular screening undertaken pre and post implementation of the intervention programmes to enhance the understanding of the impact of this screening programme.

4. Incomplete follow up
    - *This study compared results of changes between Year 1 and Year 2 and 3. Year 1 could have an anomaly in injury rates. Further longitudinal study will strengthen evidence for the use of the comprehensive medical management programme employed.*
    - *This study reported changes only over two years following changes to the comprehensive medical management programme. Longitudinal studies will strengthen the evidence of findings.*

Additional limitations or threats to evidence level across all research are:

Inconsistency;

- *This study explored the injuries to a specific cohort of professional ballet dancers. The finding relate to the comprehensive medical management programme delivered via the company's in-house medical team. The sample used was from the company in question so no limitations in regards to homogeneity were noted.*

Indirectness,

- *The findings relate directly to the target population. i.e. the professional ballet company that was studied. The external validity of the findings can be questioned to the unique and specific nature of the company and its exposure/workload alongside the nature of the intervention in the form of the comprehensive medical management programme*.

Imprecision

- *Questions over imprecision can be raised as the sample was limited to members of the company being studied. Sample size calculations* *demonstrated that the sample size used was smaller than required for improved precision of outcomes*

Publication bias

- *Publication bias may be likely in regards to the publication of chapter 4 and 5 where publication was considered due to the significant findings recorded.*

Chapter 9: References

1. .Agel, J., Olson, D. E., Dick, R., Arendt, E. A., Marshall, S. W., Sikka, R. S. (2007). Descriptive Epidemiology of Collegiate Women's Basketball Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988/1989 through 2003/2004. *Journal of Athletic Training,* **42**(2), pp.202-210.

2. Agel, J., Palmieri-Smith, R. M., Dick, R., Wojtys, E. M., Marshall, S. W. (2007). Descriptive Epidemiology of Collegiate Women's Volleyball Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988/1989 through 2003/2004. *Journal of Athletic Training,* **42**(2), pp.295-302.

3. Allen, N. Neville, A. Brooks, J. Koutedakis, Y. Wyon, M. (2012). Ballet injuires: injury incidence and severity over one year. J Orthop Sports Phys Ther Sep;42(9):781-90

4. Allen, N; Nevill, A; Brooks, J; Koutedakis, Y; Wyon, M (2013) The Effect of a Comprehensive Injury Audit Programme on Injury Incidence in Ballet: A 3-Year Prospective Study Clin J Sport Med. 2013 Sep;23(5):373-8. doi: 10.1097/JSM.0b013e3182887f32.

5. Allen, N. Wyon, M. (2008). Dance Medicine: Athlete or Artist. *SportEx Medicine*, **35**, pp.6-9.

6. Andrews, J. Guyatt, G. Oxman, A. Alderson, P. et al. (2013). GRADE guidelines: 14. Going from evidence to recommendations: the significance and presentation of recommendations. *Journal of Clinical Epidemiology*. **66**,7:pp719-725

7. Angioi, M., Twitchett, E., Metsios, G., Koutedakis, Y. and Wyon, M. (2009). Association between selected physical fitness parameters and aesthetic competence in contemporary dance. *Journal of Dance Medicine & Science*, **13**(4), pp.115-123.

8. AQA (2009) Awarding body for A-levels, GCSE's and other exams. (Accessed 1 August 2009) Available at http://www.aqa.org.uk/index.php

9. Arther, W. Bennet, Stanush, P. McNelly, T. (1998). Factors that influence skill decay and retention: A quantitive review and analysis. *Human Performance*, **11**, (1): pp.57-101.

10. The Arts Council (2009). Dance Mapping: a window on dance. (Accessed 3 August 2009) Available at http://www.artscouncil.org.uk/media/uploads/publications/dance_mapping_full_report.pdf

11. Asplund, C. Ross, M. (2010). Core stability and bicycling. *Current Sports Medicine Reports*, **9**(3), pp.155-160.

12. Atta, El-S.M., (2012). Modifying Mechanical Movement of the Attack Hit Using Neuromuscular Exercises to Prevent Injury to Players of Volleyball. *World Journal of Sport Sciences*, **6** (3): pp 222-227.

13. Augustsson, S. Augustsson, J. Thomee, R. Svantesson. (2006). Injuries and preventive actions in elite Swedish volleyball. *Scandinavian Journal of Medicine and Science in Sports*, **16**(6), pp.433-440.

14. Bahr, R. (2009). No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. *British Journal of Sports Medicine*, **43**(13), pp.966-972.

15. Bahr, R. and Bahr, I. A. (1997). Incidence of acute volleyball injuries: a prospective cohort study of injury mechanisms and risk factors. *Scandinavian Journal Of Medicine & Science In Sports*, **7**(3), pp.166-171.

16. Bahr, R., & Holme, I. (2003). Risk factors for sports injuries -- a methodological approach. *British Journal of Sports Medicine,* **37**(5), pp.384-392.

17. Bahr, R., & Krosshaug, T. (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. [Review]. *British Journal of Sports Medicine,* **39**(6), pp.324-329.

18. Balshem, H. Helfand, M. Schünemann, H. . Oxman, A. Kunz,R. Brozek, J. Vist, G. Falck-Ytter, Y. Meerpohl, J. Norris, S. Guyatt , G. (2011) GRADE guidelines: 3. Rating the quality of evidence. *Journal of Clinical Epidemiology*. **64**, 4: pp401-406

19. British Association of Sports and Exercise Medicine. (2010). Aims - Activities. (Accessed 3 August 2009) Available from http://www.basem.co.uk/aims-activities/201/false/39/201.

20. Batt, M. E., Jaques, R., & Stone, M. (2004). Preparticipation Examination (Screening): Practical Issues as Determined by Sport: A United Kingdom Perspective. *Clinical Journal of Sport Medicine,* **14**(3), pp.178-182.

21. Batten, Taylor, Cook, Pizzari, & Charlton. (2010). Key musculoskeletal screening tests used in Australian Football have limited reliability. *Journal of Science and Medicine in Sport,* **12**, e167.

22. Beales, D., O'Sullivan, Peter, Briffa, N. (2009a). Motor Control Patterns During an Active Straight Leg Raise in Chronic Pelvic Girdle Pain Subjects. *Spine*, **34**, pp.861-870.

23. Beales, D., O'Sullivan, Peter, Briffa, N. (2009b). Motor Control Patterns During an Active Straight Leg Raise in Pain-Free Subjects. *Spine*, **34**, pp.E1-E8.

24. Beattie, K. A., Bobba, R., Bayoumi, I., Chan, D., Schabort, I., Boulos, P., et al. (2008). Validation of the GALS musculoskeletal screening exam for use in primary care: a pilot study. *BMC Musculoskeletal Disorders,* **9**, pp.115-115.

25. Bennell, K., Tully, E., & Harvey, N. (1999). Does the toe-touch test predict hamstring injury in Australian rules footballers? *Australian Journal of Physiotherapy,* **45**(2), pp.103-109.

26. Bennell, K. L., Khan, K. M., Matthews, B. L., & Singleton, C. (2001). Changes in hip and ankle range of motion and hip muscle strength in 8-11 year old novice female ballet dancers and controls: a 12 month follow up study. *British Journal of Sports Medicine,* **35**(1), pp.54-59.

27. Bennett, J. E., Reinking, M. F., Pluemer, B., Pentel, A., Seaton, M., & Killian, C. (2001). Factors contributing to the development of medical tibial stress syndrome in high school runners. *Journal of Orthopaedic and Sports Physical Therapy*, **31**(9), pp.504-510.

28. Bowling, A. (1989). Injuries to dancers: prevalence, treatment, and perceptions of causes. *British Medical Journal (Clinical Research Ed.),* **298**(6675), pp.731-734.

29. Bradley, P. S., & Portas, M. D. (2007). The relationship between preseason range motion and muscle strain injury in elite soccer players. *Journal of Strength & Conditioning Research,* **21**(4), pp.1155-1159.

30. Briggs, J., McCormack, M., Hakim, A. J., & Grahame, R. (2009). Injury and joint hypermobility syndrome in ballet dancers - a 5-year follow-up. *Rheumatology,* **48**(12), pp.1613-1614.

31. Briggs, M. Givens, D. Best, T. Chaudhari, A. (2013). Lumbopelvic neuromuscular training and injury rehabilitation: a systematic review. *Clinical Journal of Sport Medicine*. **23**:160-171

32. Brinson, P., & Dick, F. (1996). Fit to dance? The report of the national inquiry into dancers health and injury. *London: Calouste Gulbenkian Foundation*.

33. Bronner, S., & Brownstein, B. (1997). Profile of dance injuries in a Broadway show: a discussion of issue in dance medicine epidemiology. *Journal of Orthopaedic & Sports Physical Therapy,* **26**(2), pp.87-94.

34. Bronner, S., Ojofeitimi, S., & Mayers, L. (2006). Comprehensive surveillance of dance injuries: a proposal for uniform reporting guidelines for professional companies. *Journal of Dance Medicine & Science,* **10**(3-4), pp.69-80.

35. Bronner, S., Ojofeitimi, S., & Rose, D. (2003). Injuries in a modern dance company. Effect of comprehensive management on injury incidence and time loss. *American Journal of Sports Medicine,* **31**(3), pp.365-373.

36. Brooks, J. H., Fuller, C. W., Kemp, S. P., Reddin, D. B. (2005). A prospective study of injuries and training amongst the England 2003 Rugby World Cup squad. *British Journal of Sports Medicine,* **39**(5), pp.288-293.

37. Brooks, J. H. M., & Fuller, C. W. (2006). The Influence of Methodological Issues on the Results and Conclusions from Epidemiological Studies of Sports Injuries: Illustrative Examples. *Sports Medicine,* **36**(6), pp.459-472.

38. Brooks, J. H. M., Fuller, C. W., Kemp, S. P. T., & Reddin, D. B. (2005a). Epidemiology of injuries in English professional rugby union: part 1 match injuries. *British Journal Of Sports Medicine,* **39**(10), pp.757-766.

39. Brooks, J. H. M., Fuller, C. W., Kemp, S. P. T., & Reddin, D. B. (2005b). Epidemiology of injuries in English professional rugby union: part 2 training Injuries. *British Journal Of Sports Medicine,* **39**(10), pp.767-775.

40. Brozek, J. Akl, E. Alonso-Coello, P. et. al. for the GRADE Working Group (2009). Grading quality of evidence and strength of recommendations in clinical practice guidelines. Part 1 of 3. An overview of the GRADE approach and grading quality of evidence about interventions. *Allergy*, **64**: pp669-677

41. Brozek, J. Akl, E. Compalati, E. et. al. for the GRADE Working Group (2011). Grading quality of evidence and strength of recommendations in clinical practice guidelines. Part 3 of 3. The GRADE approach to developing recommendations. *Allergy*, **66**:pp588-595

42. Brozek, J. Akl, E. Jaeschke, R. et. al. for the GRADE Working Group (2009). Grading quality of evidence and strength of recommendations in clinical practice guidelines. Part 2 of 3. The GRADE approach to grading quality of evidence about diagnostic tests and strategies. *Allergy*, **64**: pp1109-1116

43. Brunetti, M. Shemilt, I. Pregno, S. Vale, L. et al. (2013) GRADE guidelines: 10. Considering resource use and rating the quality of economic evidence. *Journal of Clinical Epidemiology*. **66**,2:pp140-150

44. Brushoj, C. Larsen, K. Albrecht-Beste, E. Bachmann Nielsen, M. Loye, F. Homlich, P.(2008). Prevention of overuse injuries by a concurrent exercise programme in subjects exposed to an increase in training overload: A randomized controlled trail of 1020 Army recruits. *American Journal of Sports Medicine*, **36,** pp.663-672.

45. Callaghan, M. J., & Jarvis, C. (1996). Evaluation of elite British cyclists: the role of the squad medical. *British Journal Of Sports Medicine,* **30**(4), pp.349-353.

46. Chalmers, D. J. (1994). New Zealand's Injury Prevention Research Unit: reducing sport and recreational injury. *British Journal of Sports Medicine,* **28**(4), pp.221-222.

47. Chorbra, R. Chorbra, D. Bouillon, L. Overmyer, C. Landis, J. (2010). Use of a functional movement screening tool to determine injury risk female collegiate athletes. *North American Journal of Sports Physical Therapy*. **5**, 2: 47-54

48. Chmelar, R., Fitt, B., Schultz, R., Ruhling, O., & Zupan, M. (1987). A survey of health, training and injuries in different levels and styles of dancers. *Medical Problems of Performing Artists, **2***(2), pp.61-66.

49. Choi BKL, Verbeek JH, Tam WWS, Jiang JY. Exercises for prevention of recurrences of low-back pain. *Cochrane Database of Systematic Reviews* 2010, Issue **1**. Art. No.: CD006555. DOI: 10.1002/14651858.CD006555.pub2.

50. Clippinger, K. S. (2005) Biomechanical Considerations in Turnout. *in In Solomon, Ruth (ed.), Preventing Dance Injuries. 2nd ed, Champaign, Ill., Human Kinetics, c2005, p.109;135-150.* United States.

51. Comerford, M. J. (2006). Screening to identify injury and performance risk: movement control testing - the missing piece of the puzzle. *SportEX Medicine* (29), pp21-26.

52. Cook, E., Burton, L., & Hogenboom, B. (2006a). The use of fundamental movements as an assessment of function - Part 2. *North American Journal of Sports Physical Therapy,* **1**, pp.132-139.

53. Cook, E., Burton, L., & Hogenboom, B. (2006b). The use of fundemental movements as an assessment of function - Part 1. *North American Journal of Sports Physical Therapy,* **1**, pp.62-72.

54. Coplan, J.(2002) Ballet dancers turnout and its relationship to self-reported injury. J *Orthopeadic and Sports Physical Therapy.* **32**, 11, 579-584

55. Coughlan, G. Caulfield, B. (2007). A 4-week neuromuscular training program and gait patterns at the ankle joint. *Journal of Athletic Training*. **42**(1);51-59

56. Craig, P. (2008) Developing and evaluating complex interventions: the new Medical Research Council guidance. *British Medical Journal* vol **337** p1655-1680

57. Cuff, S., Loud, K., & O'Riordan, M. A. (2010). Overuse injuries in high school athletes. *Clinical Pediatrics,* **49**(8), pp.731-736.

58. Dahlstrom, M. Inasio, J. Jansson, E. Kaijser, L.(1996) Physical fitness and physical effort in dancers: a comparison of four major dance styles. *Impulse*. 4: pp 193-209.

59. Dahm , P. Djulbegovic, B. (2011)The Australian FORM approach to guideline development: the quest for the perfect system. *BMC Medical Research Methodology* **11**:17

60. DanceUK. (2010). Dance UK - The National Voice For Dance - Dance Facts and Stats. (Accessed 8 January 2010)Available at http://www.danceuk.org/metadot/index.pl?iid=25043&isa=Category

61. Dankaerts, W. O'Sullivan, P. Burnett, A. Straker, L. (2006). Differences in sitting postures are associated with nonspecific chronic low back pain disorders when patients are subclassified. *Spine*, **31** (6), pp.698-704.

62. de Loes, M. (1997). Exposure data. Why are they needed. *Sports Medicine,* **24**(3), pp.172-175.

63. Dennis, Finch, Elliot, & Farhart. (2008). The reliability of musculoskeletal screening tests used in cricket. *Physical Therapy in Sport,* **9**, pp.25-33.

64. Dennis, A. J., Finch, C. F., McIntosh, A. S., & Elliott, B. C. (2008). Use of field-based tests to identify risk factors for injury to fast bowlers in cricket. *British Journal of Sports Medicine,* **42**(6), pp.477-482.

65. De Vries, JS. Krips, R. Sierevelt, IN. et. al.(2011). Interventions for treating chronic ankle instability. *Cochrane Database Syst Rev*. **8**:CD004124

66. Dick, R., Agel, J., & Marshall, S. W. (2007a). National Collegiate Athletic Association Injury Surveillance System Commentaries: Introduction and Methods. *Journal of Athletic Training,* **42**(2), pp.173-182.

67. Dick, R., Hertel, J., Agel, J., Grossman, J. and Marshall, S. W. (2007b). Descriptive Epidemiology of Collegiate Men's Basketball Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988/1989 through 2003/2004. *Journal of Athletic Training*, **42**(2), pp.194-201.

68. Dick, R., Hootman, J. M., Agel, J., Vela, L., Marshall, S. W., & Messina, R. (2007c). Descriptive Epidemiology of Collegiate Women's Field Hockey Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988/1989 through 2002/2003. *Journal of Athletic Training,* **42**(2), pp.211-220.

69. Dick, R., Sauers, E. L., Agel, J., Keuter, G., Marshall, S. W., McCarty, K., et al. (2007d). Descriptive Epidemiology of Collegiate Men's Baseball Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988/1989 through 2003/2004. *Journal of Athletic Training,* **42**(2), pp.183-193.

70. Department of Health. (2009). *Be Active be Healthy*. (Accessed 8 August 2009) Available at

http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_094359.pdf.

71. Drawer, S., & Fuller, C. W. (2001). Propensity for osteoarthritis and lower limb joint pain in retired professional soccer players... including commentary by Waddington I. *British Journal of Sports Medicine,* **35**(6), pp.402-408.

72. Elwood, J. (1988). *Causal relationship in medicine. A practical system for critical appraisal.* Oxford University Press.

73. Emery, C. Meeuwisse, W. (2007). The effectiveness of a neuromuscular prevention strategy to reduce injuries in youth soccer: a cluster-randomised control trial. *British Journal of Sports Medicine,* **44**(8), pp.555-562.

74. Engebretsen, L., & Bahr, R. (2005). An ounce of prevention? *British Journal of Sports Medicine,* **39**(6), pp.312-313.

75. Evans, R., W., Evans, R. I., & Carvajal, S. (1996). Survey of injuires among Broadway performers: Types of injuires, treatments and perceptions of performers. *Medical Problems of Performing Artists,* **11**(1), pp.15-19.

76. Health and Safety Executive, (2009) *Health and Safety at work etc Act: 1974*. (Accessed 8 August 2009) Available at http://www.hse.gov.uk/legislation/hswa.pdf.

77. Federici, A. Bellagamba, S. Rocchi, M. (2005). Does dance based training improve balance in adult and young old subjects? A pilot randomized control trial. *Aging clinical and experimental research*, vol **17**, no 5, pp 385-389

78. Fentem, P. H. (1994). ABC of Sports Medicine: Benefits of exercise in health and disease. *British Medical Journal,* **308**(6939), pp.1291-1295.

79. Fields, K. Sykes, J. Walker, K. Jackson, J.(2010). Prevention of running injuries. *Current Sports Medicine Reports*, **9**(3), pp.176-182.

80. Finch, C. F. (1997). An overview of some definitional issues for sports injury surveillance. *Sports Medicine,* **24**(3), pp.157-163.

81. Fuller. (1995). Implications of health and safety legislation for the professional sportsperson. *British Journal of Sports Medicine,* **29**, pp.5-9.

82. Fuller, C. W., Brooks, J. H. M., & Kemp, S. P. T. (2007). Spinal injuries in professional rugby union: a prospective cohort study. *Clinical Journal of Sport Medicine,* **17**(1), pp.10-16.

83. Fuller, C. W., Bahr, R., Dick, R. W. and Meeuwisse, W. H. (2007a). A framework for recording recurrences, reinjuries, and exacerbations in injury surveillance. *Clinical Journal of Sport Medicine*, **17**(3), pp.197-200.

84. Fuller, C. and Drawer, S. (2004). The application of risk management in sport. *Sports Medicine*, **34**(6), pp.349-356.

85. Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., Dvorak, J., et al. (2006). Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scandinavian Journal of Medicine & Science in Sports,* **16**(2), pp.83-92.

86. Fuller, C. W., Hawkins, R. D., Dent, A. R., & Harling, C. C. (1997). Developing a health surveillance stratgegy for professional footballers in compliance with UK health and safety legislation/Developper une strategie de controle sanitaire chez les footballeurs professionnels conformement a la legislation britannique en matiere de sante et de securite. *British Journal of Sports Medicine,* **31**(2), pp.148-150.

87. Fuller, C. W., Molloy, M. G., Bagate, C., Bahr, R., Brooks, J. H. M., Donson, H., et al. (2007b). Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Clinical Journal Of Sport Medicine: Official Journal Of The Canadian Academy Of Sport Medicine,* **17**(3), pp.177-181.

88. Fuller, C. W., Ojelade, E. O., & Taylor, A. (2007c). Preparticipation medical evaluation in professional sport in the UK: theory or practice? *British Journal of Sports Medicine,* **41**(12), pp.890-896.

89. Fransen M, McConnell S. Exercise for osteoarthritis of the knee.(2008) *Cochrane Database of Systematic Reviews.* Issue **4.** Art. No.: CD004376. DOI: 10.1002/14651858.CD004376.pub2

90. Fransen M, McConnell S, Hernandez-Molina G, Reichenbach S. (2009). Exercise for osteoarthritis of the hip. *Cochrane Database of Systematic Reviews*, Issue 3. Art. No.: CD007912. DOI: 10.1002/14651858.CD007912

91. Gabbe, B. J., Bennell, K. L., Wajswelner, H., & Finch, C. F. (2004). Reliability of common lower extremity musculoskeletal screening tests. *Physical Therapy in Sport*, *5*(2), 90-97.

92. Gabbe, B. J., Finch, C. F., Bennell, K. L., & Wajswelner, H. (2003). How valid is a self reported 12 month sports injury history? *British Journal of Sports Medicine,* **37**(6), pp.545-547.

93. Gabbett, T. J. (2003). Incidence of injury in semi-professional rugby league players... including commentary by Phillips JH. *British Journal of Sports Medicine,* **37**(1), pp.36-44.

94. Gamboa, J.M., Roberts, L.A., Maring, J., & Fergus, A. (2008). Injury Patterns in Elite Preprofessional Ballet Dancers and the Utility of Screening Programs to Identify Risk Characteristics. *Journal of Orthopaedic and Sports Physical Therapy,* **38**(3), pp.126-136.

95. Garcia-Pallares, J. Carrasco, L.Diaz, A. Sanchez-Medina, L. (2009). Post-season detraining effects on physiological and performance parameters in top-level kayakers: comparison of two recovery strategies. *Journal of Sports Science and Medicine,* **8**, pp.622-628.

96. Garrick, J. G. and Requa, R. K. (1993). Ballet injuries: an analysis of epidemiology and financial outcome. *American Journal of Sports Medicine,* **21** (4), pp.586-590.

97. Gribble, PA, Brigle, J, Pietrosimone, BG, Pfile, KR, and Webster, KA. Intrarater reliability of the functional movement screen. *Journal of Strength Conditioning Research* **27** (4): 978-981, 2013

98. Programs and non contact anterior cruciate ligament rates in female athletes: a numbers-needed-to-treat analysis. *Journal of Athletic Training,* **41** (4), pp.450-456

99. Guyatt, G. Oxman,A. Akl, E. Kunz, R. Vist, G. Brozek, J. Norris,S. Falck-Ytter, Y. Glasziou, P. deBeer,H. Jaeschke, R. Rind, D. Meerpohl, J. Dahm, P. Schünemann, H. (2011) GRADE guidelines: 1. Introduction—GRADE evidence profiles and summary of findings tables. *Journal of Clinical Epidemiology*. **64**, 4:pp383-394

100. Guyatt, G. Oxman, A. Kunz, R. Atkins, D. et al. (April 2011) GRADE guidelines: 2. Framing the question and deciding on important outcomes. *Journal of Clinical Epidemiology*. **64**, 4:pp395-400

101. Guyatt, G. Oxman, A. Vist, G. Kunz, R. et al. (April 2011) GRADE guidelines: 4. Rating the quality of evidence—study limitations (risk of bias). *Journal of Clinical Epidemiology*. **64**, 4:pp407-415

102. Guyatt, G. Oxman, A. Montori, V. Vist, G. et al. (2011). GRADE guidelines: 5. Rating the quality of evidence—publication bias. *Journal of Clinical Epidemiology*. **64**, 12;pp1277-1282

103. Guyatt, G. Oxman, A. Kunz, R. Brozek, J. et al. (2011) GRADE guidelines 6. Rating the quality of evidence—imprecision. *Journal of Clinical Epidemiology*. **64**, 12:pp1283-1293

104. Guyatt, G.. Oxman, A. Kunz, R. Woodcock, J. et al. (2011) GRADE guidelines: 7. Rating the quality of evidence—inconsistency. *Journal of Clinical Epidemiology*. **64**, 12:pp1294-1302

105. Guyatt, G. Oxman, A. Kunz, R. Woodcock, J. et al. (2011). GRADE guidelines: 8. Rating the quality of evidence—indirectness. *Journal of Clinical Epidemiology*. **64**, 12:pp1303-1310

106. Guyatt, G. Oxman, A. Sultan, S. Glasziou, P. et al. (2011) GRADE guidelines: 9. Rating up the quality of evidence. *Journal of Clinical Epidemiology*. **64**, 12:pp1311-1316

107. Guyatt, G. Oxman, A. Sultan, S. Brozek, J. et al. (2013) GRADE guidelines: 11. Making an overall rating of confidence in effect estimates for a single outcome and for all outcomes. *Journal of Clinical Epidemiology*. **66**, 2:pp151-157

108. Guyatt, G. Oxman, A. Santesso, N. Helfand, M. et al. (2013). GRADE guidelines: 12. Preparing Summary of Findings tables—binary outcomes. J*ournal of Clinical Epidemiology.* **66**, 2:pp158-172

109. Guyatt, G. Thorlund, K. Oxman, A. Walter, S. et al. (2013) GRADE guidelines: 13. Preparing Summary of Findings tables and evidence profiles—continuous outcomes. *Journal of Clinical Epidemiology*. **66**, 2:pp173-183

110. Hakkinen, A., Makinen, H., Ylinen, J., Hannonen, P., Sokka, T., Neva, M., Kautiainen, H. and Kauppi, M. (2008). Stability of the upper neck during isometric neck exercises in rheumatoid arthritis patients with atlantoaxial disorders. *Scandinavian Journal Of Rheumatology*, **37**(5), pp.343-347.

111. Halbertsma, J. P. K., Göeken, L. N. H., Hoff, A. L., Groothoff, J. W., & Eisma, W. H. (2001). Extensibility and stiffness of the hamstring in patients with nonspecific low back pain. *Archives of Physical Medicine & Rehabilitation,* **82**(2), pp.232-238.

112. Hamilton D, Aronsen P, Løken J, et. al. (2006). Dance training intensity at 11–14 years is associated with femoral torsion in classical ballet dancers. *British Journal of Sports Medicine,* **40**, pp.299-303.

113. Hamilton, W. G., Hamilton, L. H., Marshall, P., & Molnar, M. (1992). A profile of the musculoskeletal characteristics of elite professional ballet dancers. The American *Journal of Sports Medicine*, **20**(3),pp 267-273.

114. Harringe, M. L., Renstrom, P., & Werner, S. (2007). Injury incidence, mechanism and diagnosis in top-level teamgym: a prospective study conducted over one season. *Scandinavian Journal of Medicine & Science in Sports,* **17**(2), pp.115-119.

115. Hawkins, R. D., & Fuller, C. W. (1999). A prospective epidemiological study of injuries in four English professional football clubs. *British Journal Of Sports Medicine,* **33**(3), pp.196-203.

116. Hayen, A., Dennis, R., & Finch, C. (2007). Determining the intra- and inter-observer reliability of screening tools used in sports injury research. *Journal of Science & Medicine in Sport,* **10**(4), pp.201-210.

117. Hayden J, van Tulder MW, Malmivaara A, Koes BW. (2005) Exercise therapy for treatment of non-specific low back pain. *Cochrane Database of Systematic Reviews* 2005, Issue **3**. Art. No.: CD000335. DOI: 10.1002/14651858.CD000335.pub2.

118. Hägglund, M., Waldén, M. and Ekstrand, J. (2006). Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *British Journal of Sports Medicine*, **40**(9), pp.767-772.

119. Hägglund, M., Waldén, M. and Ekstrand, J. (2009). UEFA injury study--an injury audit of European Championships 2006 to 2008. *British Journal of Sports Medicine*, **43**(7), pp.483-489.

120. Heintjes EM, Berger M, Bierma-Zeinstra SMA, Bernsen RMD, Verhaar JAN, Koes BW. (2003). Exercise therapy for patellofemoral pain syndrome. *Cochrane Database of Systematic Reviews*, Issue 4. Art. No.: CD003472. DOI: 10.1002/14651858.CD003472.

121. Herbert, R. D., & Gabriel, M. (2002). Effects of stretching before and after exercising on muscle soreness and risk of injury: systematic review. *British Medical Journal,* **325**(7362), pp.468-473.

122. Herman, K. Barton, C. Malliaras, P. Morrissey, D. (2012). The effectiveness of neuromuscular warm-up strategies, that require no additional equipment, for preventing lower limb injuries during sports participation: a systematic review. *BMC Medicine*, 10:75

123. Hershman, E. (1984). The profile for prevention of musculoskeletal injury. *Clinics in Sports Medicine,* **3**(1), pp.65-84.

124. Hewett, T. Ford, K. Myer, G. (2006). Anterior cruciate ligament injuries in female athletes: part 2, a meta-analysis of neuromuscular interventions aimed at injury prevention. *The American Journal of Sports Medicine,* **34**(3), pp.490-498.

125. Higher Education Statistics Agency. (2009). HESA (Accessed 8 August 2009) Available at http://www.hesa.ac.uk/

126. Hides, J. Jull, G. Richardson, C. (2001). Long term effects of specific stabilizing exercises for first episode low back pain. *Spine*, **26**(11), pp.243-248.

127. Hincapie, C. A., Morton, E. J., & Cassidy, J. D. (2008). Musculoskeletal injuries and pain in dancers: a systematic review. *Archives of Physical medicine and Rehabilitation,* **89**(9), pp.1819-1829.

128. Hodges, P. Moseley, G. (2003). Pain and motor control of the lumbo-pelvic region: Effect and possible mechanisms. *Journal of Electromyography and Kinesiology*, **4**, pp.361-370.

129. Hodges, P., & Richardson, C. (1996). Inefficient muscular stabilization of the lumbar spine associated with low back pain: a motor control evaluation of transverse abdominis. *Spine,* **21**, pp.2640-2650.

130. Hodgson-Phillips, L. (2000). Sports injury incidence. *British Journal of Sports Medicine*, **34**(2), pp.133-136.

131. Hodgson, L. Gissane, C. Gabbett, T. King, D. (2007). For Debate: consensus injury definitions in team sports should focus on encompassing all injuries. *Clinical Journal of Sport Medicine*, **17**(3), pp.188-191.

132. Hopper, L. Allen, N. Wyon, M. Alderson, JA. Elliot, BC. Ackland, T. (2013). Dance floor mechanical properties and dancers injuirs in a touring professional ballet company. *J Med Sci* 17 (1) pp 29-33

133. Hoy, K., Lindblad, B. E., Terkelsen, C. J., & Helleland, H. E. (1992). European soccer injuries: a prospective epidemiologic and socioeconomic study. *American Journal of Sports Medicine,* **20**(3), pp.318-322.

134. Hubscher, M. Zech, A. Pfeifer, K. Hansel, F. Vogt, L. Banzer, W. (2010). Neuromuscular training for sports injury prevention: a systematic review. *Medicine and Science in Sports and Exercise*, **42**(3), pp.413-421.

135. Hungerford, B. Gilleard, W. Hodges, P. (2003). Evidence of altered lumbopelvic muscle recruitment in the presence of sacroiliac joint pain. *Spine*, **28**(14), pp.1593-1600.

136. Hupperets, M. Verhagen, E. Heymans, M. Bosmans, J. van Tulder, M. van Mechelen, W. (2010). Potential savings of a program to prevent ankle sprain recurrence: economic evaluation of a randomized controlled trial. *American Journal of Sports Medicine*, **38**(11), pp.2194-2000.

137. International Association of Dance Medicine and Science (2009). IADMS. (Accessed 8 August 2009) Available at http://www.iadms.org/displaycommon.cfm?an=8

138. Jacobs, C. Hincapie, C. Cassidy, J. (2012). Musculoskeletal injuries and pain in dancers. A systematic review update. *Journal of Dance Medicne and Science*. **16**,2, pp74-84.

139. Jadad, A. Cook, D. Jones, A. Klassen, T, Tugwell, P. Moher, M. Moher, D. (1998). Methodology and reports of systematic reviews and meta-analyses: a comparison of Cochrane reviews with articles published in paper based journals. *Journal of the American Medical Association* **280**:278-280

140. Janda. (1997). Sports injury surveillance had everything to do with sports medicine. *Sports Medicine,* **24**(3), pp.169-171.

141. Jain, S., & Brown, D. R. (2001). Cultural dance: an opportunity to encourage physical activity and health in communities. *American Journal of Health Education,* **32**(4), pp.216-222.

142. Jones, R. S., & Taggart, T. (1994). Sport related injuries attending the accident and emergency department. *British Journal Of Sports Medicine,* **28**(2), pp.110-111.

143. Juni, P. Altman, DG. Egger, M. (2001) Systematic reviews in health care: assessing the quality of controlled clinical trials. *British Medical Journal* 323: pp. 42-46

144. Jull, G. Trott, P. Potter, H. Zito, G. Niere, K. Shirley, D. et. al. (2002). A randomized controlled trial of exercise and manipulative therapy for cervicogenic headache. *Spine*, **27**(17), pp.1835-1843.

145. Kay TM, Gross A, Goldsmith CH, Hoving JL, Brønfort G. Exercises for mechanical neck disorders. *Cochrane Database of Systematic Reviews* 2005, Issue **3**. Art. No.: CD004250. DOI: 10.1002/14651858.CD004250.pub3.

146. Kiesel, Plisky, & Voight. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen? *North American Journal of Sports Physical Therapy,* **2**(3), pp.147-158.

147. Keogh, J. Kilding, A. Pidgeon, P. Ashley, L. Gillis, D. (2009). Physical benefits of dancing for healthy older adults: A review. *Journal of Aging and Physical Activity*. **17**, 1-23

148. Khan, K., Brown, J., Way, S., Vass, N., Crichton, K., Alexander, R., et al. (1995). Overuse injuries in classical ballet. *Sports Medicine,* **19**(5), pp.341-357.

149. Kiesel, Plisky, & Voight. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen? *North American Journal of Sports Physical Therapy,* **2**(3), pp.147-158.

150. Klemp, P. and Learmonth, I. (1984). Hypermobility and injuries in a professional ballet company. *British Journal of Sports Medicine*, **18**, pp.143-148.

151. Koutedakis, Y., Agrawal, A., & Sharp, N. C. C. (1999). Isokinetic characteristics of knee flexors and extensors in male dancers, Olympic oarsmen, Olympic bobsleighers, and non-athletes. *Journal of Dance Medicine and Science,* **2**(2), pp.63-67.

152. Koutedakis, Y., & Jamurtas, A. (2004). The dancer as a performing athlete: physiological considerations. *Sports Medicine,* **34**(10), pp.651-661.

153. Koutedakis, Y., Stavropoulos-Kalinoglou, A., & Metsios, G. (2005). The Significance of Muscular Strength in Dance. *Journal of Dance Medicine and Science,* **9**(1), pp.29-34.

154. Kujala, U. M., Taimela, S., Antti-Poika, I., Orava, S., Tuominen, R., & Myllynen, P. (1995). Acute injuries in soccer, ice hockey, volleyball, basketball, judo, and karate: analysis of national registry data. *British Medical Journal,* **311**(7018), pp.1465-1468.

155. Last JM, ed. A dictionary of epidemiology. 4th edition. New York: Oxford University Press, 2001.

156. Laws, H. (2005). *Fit to Dance 2 - Report of the second national inquiry into dancers' health and injury in the UK*. London: Newgate Press.

157. Laws, H. (2003). Initial findings of the second national inquiry into dancers' health and injury in the UK: a comparison study. *Journal of Dance Medicine & Science,* **7**(2), pp.62-63.

158. Lee, A. J., Garraway, W. M., Hepburn, W., & Laidlaw, R. (2001). Influence of rugby injuries on players' subsequent health and lifestyle: beginning a long term follow up. *British Journal of Sports Medicine,* **35**(1), pp.38-42.

159. Leiderbach, M. (2010). Perspectives on dance science rehabilitation. Understanding the whole body mechanics and principals of motor control as a basis for healthy movement. *Journal of Dance Medicine and Science*, **14**(3), pp.114-124.

160. Liederbach, M. (1997). Screening for functional capacity in dancers: designing standardized, dance-specific injury prevention screening tools. *Journal of Dance Medicine & Science,* **1**(3), pp.93-106.

161. Leiderbach, M. Higgins, Gamboa, J.M. Welsh (2012) Assessing and Reporting Dancer Capacities, Risk Factors, and Injuries: Recommendations from the IADMS Standard Measures Consensus Initiative *Journal of Dance Medicine and Science* **16** (4) p139-153

162. Liederbach, M., & Richardson, M. (2007). The importance of standardized injury reporting in dance. *Journal of Dance Medicine & Science,* **11**(2), pp.45-48.

163. Lin, C.C. Delahunt, E. King, E. (2012). Neuromuscular training for chronic ankle instability. *Physical Therapy*. **92**:987-991

164. Lindblad, B. E., Hoy, K., Terkelsen, C. J., & Helleland, H. E. (1992). Handball injuries: an epidemiologic and socioeconomic study. *American Journal of Sports Medicine,* **20**(4), pp.441-444.

165. Ljungqvist, A., Jenoure, P., Engebretsen, L., Alonso, J. M., Bahr, R., Clough, A., De Bondt, G., Dvorak, J., Maloley, R., Matheson, G., Meeuwisse, W., Meijboom, E., Mountjoy, M., Pelliccia, A., Schwellnus, M., Sprumont, D., Schamasch, P., Gauthier, J. B., Dubi, C., Stupp, H. and Thill, C. (2009). The International Olympic Committee (IOC) Consensus Statement on periodic health evaluation of elite athletes March 2009. *British Journal of Sports Medicine*, **43**(9), pp.631-643.

166. Lorentzon, R., Wedren, H. and Pietilae, T. (1988). Incidence, nature, and causes of ice hockey injuries. A three-year prospective study of a Swedish elite ice hockey team / Incidence, nature et causes des lesions en hockey sur glace: etude prospective de 3 ans sur une equipe suedoise de haut niveau en hockey sur glace. *American Journal of Sports Medicine*, **16**(4), pp.392-396.

167. Luke, A. C., Kinney, S. A., D'hemecourt, P. A., Baum, J., Owen, M. and Micheli, L. J. (2002). Determinants of injuries in young dancers. *Medical Problems of Performing Artists*, **17**(3), pp.105-112.

168. Lundon, K., Melcher, L., & Bray, K. (1999). Stress fractures in ballet: a twenty-five year review. *Journal of Dance Medicine & Science,* **3**(3), pp.101-107.

169. Lüthje, P., Nurmi, I., Kataja, M., Belt, E., Helenius, P., Kaukonen, J. P., et al. (1996). Epidemiology and traumatology of injuries in elite soccer: a prospective study in Finland. *Scandinavian Journal Of Medicine & Science In Sports,* **6**(3), pp.180-185.

170. Macintyre, J. and Joy, E. (2000). Foot and ankle injuries in dance. *Clinics in Sports Medicine,* **19**(2), p.351-368.

171. Malterud, K. (2001) *The Lancet*; Aug 4; 358, 9279; ProQuest Nursing & Allied Health Sourcepg. pp397-400

172. Manchikanti, L. (2008). Evidence –based medicine, systematic reviews, and guidelines in interventional pain management, part 1: introduction and general considerations. *Pain Physician*, **11**:pp161-186

173. Mandelbaum, B. Silvers, H. Watanabe, D. Knarr, J. Thomas, S. Griffin, L. Kirkendall, D. Garett, W. (2005). Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes. *American Journal of Sports Medicine.* **33**(7), pp.1003-1010.

174. Marshall, S. W., Covassin, T., Dick, R., Nassar, L. G., & Agel, J. (2007). Descriptive Epidemiology of Collegiate Women's Gymnastics Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988/1989 through 2003/2004. *Journal of Athletic Training,* **42**(2), pp.234-240.

175. Marshall, P. W., Mannion, J., & Murphy, B. A. (2010). The eccentric, concentric strength relationship of the hamstring muscles in chronic low back pain. *Journal of Electromyography & Kinesiology,* **20**(1), pp.39-45.

176. McCormack, M., Briggs, J., Hakim, A., & Grahame, R. (2004). Joint laxity and the benign joint hypermobility syndrome in student and professional ballet dancers. *Journal of Rheumatology,* **31**(1), pp.173-178.

177. McGill, S. (2010). Core training: evidence translating to better performance and injury prevention. *Strength and Conditioning Journal*, **32**(3), pp.33-46.

178. Meeuwisse, W. H. (1991). Predictability of sports injuries. What is the epidemiological evidence? *Sports Medicine (Auckland, N.Z.),* **12**(1), pp.8-15.

179. Meeuwisse, W. H. (1994). Assessing causation in sport injury: a multifactorial model. *Clinical Journal of Sport Medicine,* **4**(3), pp.166-170.

180. Meeuwisse, W. H., & Love, E. J. (1997). Athletic injury reporting: development of universal systems. *Sports Medicine,* **24**(3), pp.184-204.

181. Meeuwisse, W.H. and E.J. Love (1997). Athletic injury reporting: development of universal systems. *Sports Medicine*. **24**(3): p. 184-204.

182. Meeuwisse, Sellmer and Hagel (2003). Rates and Risks of Injury during Intercollegiate Basketball. *American Journal of Sports Medicine*, **31**(3), pp.379-385.

183. Meeuwisse, W. H., Tyreman, H., Hagel, B., & Emery, C. (2007). A Dynamic Model of Etiology in Sport Injury: The Recursive Nature of Risk and Causation. *Clinical Journal of Sport Medicine,* **17**(3), pp.215-219.

184. Menetrey, J., & Fritschy, D. (1999). Subtalar subluxation in ballet dancers. *American Journal of Sports Medicine,* **27**(2), pp.143-149.

185. Mens, J., Stam, H., Vleeming, A., & Snijders, C. (1995). *Active straight leg raiseing. A clinical approach to the load transfer function of the pelvic girdle*. Rotterdam: ECO.2nd Interdisciplinary World Congress on Low Back Pain, pp. 207-220

186. Meyer, J. (2000) Qualitative research in health care. Using qualitative methods in health related action research. *British Medical Journal* **320**:pp178-81

187. Milan, K. R. (1994) Injury in ballet: a review of relevant topics for the physical therapist. *Journal of Orthopaedic & Sports Physical Therapy*, **19**(2), pp.121-129.

188. Milan, K. (1996). Literature review of common injuries in the performing artist. *Orthopaedic Physical Therapy Clinics of North America*, **5**(4),pp:421-453

189. Minick, K. I., Kiesel, K. B., Burton, L., Taylor, A., Plisky, P., & Butler, R. J. (2010). Interrater reliability of the functional movement screen. *Journal of Strength & Conditioning Research,* **24**(2), pp. 479-486.

190. Miyamoto, R. G., Dhotar, H. S., Rose, D. J., & Egol, K. (2009). Surgical treatment of refractory tibial stress fractures in elite dancers: a case series. *The American Journal Of Sports Medicine,* **37**(6), pp.1150-1154.

191. Moher, D. Liberati, A. Tetzlaff, J. Altman, D. The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analysis: The PRISMA statement. *PLoS Med* 6(6): e1000097.doi:10.137/journal.pmed 1000097

192. Moseley, G. Hodges, P. (2006). Reduced variability of postural strategy prevents normalisation of motor changes induced by back pain: A risk factor for chronic trouble? *Behavioural neuroscience*, **120**(2), pp.474-476.

193. Mottram, S., & Comerford, M. (2008). A new perspective on risk assessment. *Physical Therapy in Sport,* **9**(1), pp.40-51.

194. Murphy, D. F., Connolly, D. A. J., & Beynnon, B. D. (2003). Risk factors for lower extremity injury: a review of the literature. *British Journal of Sports Medicine,* **37**(1), pp.13-29.

195. Myer, G. Ford, K. Palumbo, J. Hewett, T. (2005). Neuromuscular training improves performance and lower extremity biomechanics in female athletes. *Journal of Strength and Conditioning Research*, **19**(1), pp.51-60.

196. Myklebust, G. and Bahr, R. (2005). Return to play guidelines after anterior cruciate ligament surgery. *British Journal of Sports Medicine*, **39**(3), pp.127-131.

197. Nicholl, J. P., Coleman, P., & Williams, B. T. (1995). The epidemiology of sports and exercise related injury in the United Kingdom. *British Journal of Sports Medicine,* **29**(4), pp.232-238.

198. Nilsson, C., Leanderson, J., Wykman, A., & Strnder, L. E. (2001). The injury panorama in a Swedish professional ballet company. *Knee Surgery, Sports Traumatology, Arthroscopy,* **9**(4), pp.242-246.

199. O’Conner,F. Deuster, P. Davis, J. Pappas, C. Knapik, J. (2011). Functional movement screening: Predicting injuries in officer candidates. *Medicine and Science in Sports and Exercise*. Vol. **43**, No. 12, pp. 2224–2230

200. O’Driscoll, J. Delahunt, E. (2011). Neuromuscular training to enhance sensorimotor and functional deficits in subjects with chronic ankle instability: a systematic review and best evidence synthesis. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy and Technology*. **3**:19

201. O'Mailia, S. P., Scharff-Olson, M., & Williford, H. N. (2002). Activity monitors and dance-based exercise: estimating caloric expenditure. *Journal of Dance Medicine & Science,* **6**(2), pp.50-53.

202. OpenEpi sample size calculator for a descriptive study (http://www.openepi.com/OE2.3/SampleSize/SSPropor.htm)

203. Orchard, J. (1993) Orchard Sports Injury Classification System (OSICS). *Sport Health*, **11**(3), pp.39-41.

204. Orchard, J. Hoskins, W. (2007). For debate: consensus injury definitions in team sports should focus on missed playing time. *Clinical Journal of Sport Medicine*, **17**(3), pp.192-196.

205. Orchard, & Seward. (2009). Injury Report 2008. 090602 Australian Football League, pp:1-14.

206. Orchard, J., & Seward, H. (2002). Epidemiology of injuries in the Australian Football League, seasons 1997-2000. *British Journal of Sports Medicine,* **36**(1), pp.39-44.

207. Orchard, J. W. (2008). Preventing sports injuries at the national level: time for other nations to follow New Zealand's remarkable success. *British Journal of Sports Medicine,* **42**(6), pp.392-393.

208. Onate, J. Dewey, T. Kollock, R. Thomas, K. Van Lunen, B. DeMaio, M. Ringler, S. (2012). Real-time intersession and interrater reliability of the functional movement screen. *Journal of Strength and Conditioning Research* **26**.(2):408-415

209. O'Sullivan, P. (2005). Diagnosis and classification of chronic low back pain disorders: Maladaptive movement and motor control impairments as underlying mechanisms. *Manual Therapy*, **10**(4), pp.242-255.

210. O'Sullivan, P. (2000). Lumbar segmental "instability" clinical presentation and specific stabilizing exercise management. *Manual Therapy*, **5**(1), pp.2-12.

211. O'Sullivan, P. Twomey, L. Allison, G. (1997). Evaluation of specific stabilisation exercise in the treatment of chronic low back pain with a radiological diagnosis of spondylosis or spondylolisthesis. *Spine*, **22**(24), pp.2959-2967.

212. Panics, G. Tallay, A. Pavlik, A. Berkes, I. (2008) Effect of proprioception training on knee joint position sense in female team handball players. *British Journal of Sports Medicine*. **42**(6):472-476

213. Parkkari, J., Kujala, U. M., & Kannus, P. (2001). Is it possible to prevent sports injuries? Review of controlled clinical trials and recommendations for future work. *Sports Medicine,* **31**(14), pp.985-995.

214. Peate, Bates, Lunda, Francis, & Bellamy. (2007). Core strength: A new model for injury prediction and prevention. *Journal of Occupational Medicine and Toxicology, 2*(3), pp:1-9.

215. Pedersen, M. E., & Wilmerding, V. (1998). Injury profiles of student and professional flamenco dancers. *Journal of Dance Medicine & Science,* **2**(3), pp.108-114.

216. Penrod, J. (1994). Expression in dance: teaching beyond technique. *Impulse,* **2**, pp.3-15.

217. Peterson, L., Junge, A., Chomiak, J., Graf-Baumann, T. and Dvorak, J. (2000). Incidence of football injuries and complaints in different age groups and skill-level groups. *American Journal of Sports Medicine*, **28**(5), pp.S51-57.

218. Petersen, E. J., & Smith, K. C. (2007). Benefits of a musculoskeletal screening examination for Initial Entry Training soldiers. *Military Medicine,* **172**(1), pp.92-97.

219. Peterson, M. Rhea, M. and Alvar, B. (2005). Applications of the dose response for muscular development: a review of meta-analytic efficiency and reliability for designing training prescription. *Journal of Strength and Conditioning Research,* **19**(4), pp.950-958.

220. Phillips, H.(2000) Sports injury incidence. *British Journal of Sports Medicine*,. **34**: pp 133-136.

221. Phillips, L. H., Standen, P. J., & Batt, M. E. (1998). Effects of seasonal change in rugby league on the incidence of injury. *British Journal of Sports Medicine,* **32**(2), pp.144-148.

222. Pluim, B. M., Fuller, C. W., Batt, M. E., Chase, L., Hainline, B., Miller, S., et al. (2009). Consensus statement on epidemiological studies of medical conditions in tennis, April 2009. *British Journal Of Sports Medicine,* **43**(12), pp.893-897.

223. Prisk, V. O'Loughlin, P. Kennedy, J.(2008). Forefoot injuries in dancers. *Clinics in Sports Medicine*, **27**(2), pp.305-320.

224. Pool-Goudzwaard, A. L., Vleeming, A., Stoeckart, R., Snijders, C. J., & Mens, J. M. (1998). Insufficient lumbopelvic stability: a clinical, anatomical and biomechanical approach to "a-specific" low back pain. *Manual Therapy*, **3**(1), pp.12-20.

225. Quirk, R. (1983). Ballet injuries: the Australian experience. *Clinics in Sports Medicine,* **2**(3), pp.507-514.

226. Ramal, E., & Moritz, U. (1994). Self reported musculoskeletal pain and discomfort in professional ballet dancers in sweden. *Scandinavian Journal of Rehabilitaion Medicine,* **26**(1), pp.11-16.

227. Ramal, E., Moritz, U., & Jarnlo, G. (1996). Recurrent musculo-skeletal pain in professional ballet dancers in Sweden: A six-year follow up. *Journal of Dance Medicine and Science,* **3**(3), pp.93-100.

228. Russell, B. (1991). A study of lumbopelvic dysfunction/psoas insufficiency and its role as a major cause of dance injury. *Chiropractic Sports Medicine,* **5**(1), pp.9-17.

229. Russell, Shave, Yoshioka, Kruse, Koutedakis and Wyon (2010). Magnetic resonance imaging of the ankle in female ballet dancers en pointe. *Acta Radiologica*, **51**(6), pp.655-661.

230. Sampsize: Sample size and Power V0.6 (2003) for sample size for a prevalence survey, with finite population correction (http://sampsize.sourceforge.net/iface/).

231. Sands, W. A., Shultz, B. B. and Newman, A. P. (1993). Women's gymnastics injuries: a 5-year study. *American Journal of Sports Medicine*, **21**(2), pp.271-276.

232. Schmoor, C., Sauerbrei, W., & Schumacher, M. (2000). Sample size considerations for the evaluation of prognostic factors in survival analysis. *Statistics in Medicine,* **19**(4), pp.441-452.

233. Schulz, K. Altman, D. Moher, D. (2010) CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. *British Medical Journa*l; **340**: 698-702

234. Scott, G. (1997). Banes and Carroll on defining dance. *Dance Research Journal*, **29**(1), pp.7-23.

235. Schon, L. Biddinger, K. Greenwood, P. (1994). Dance screen programs and development of dance clinics. *Clinics in Sports Medicine*, **13**(4), pp.865-882.

236. Shah, S. (2008). Caring for the dancer: Special considerations for the performer and troupe. *Current Sports Medicine Reports*, **7**(3), pp.28- 132.

237. Shea, B. Grimshaw, J. Wells, G. Boers, M. Andersson, N. Hamel, C. Porter, A. Tugwell, P. Moher, D. Bouter, L. (2007) Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. *BMC Medical Research Methodology*, **7**:10 doi10.1186/1471-2288-7-10

238. Shrier, I., Meeuwisse, W. H., Matheson, G. O., Wingfield, K., Steele, R. J., Prince, F., et al. (2009). Injury Patterns and Injury Rates in the Circus Arts: An Analysis of 5 Years of Data From Cirque du Soleil. *American Journal of Sports Medicine,* **37**(6), pp.1143-1149.

239. Siev-Ner, I., Barak, A., Heim, M., Warshavsky, M., & Azaria, M. (1997). The value of screening. *Journal of Dance Medicine & Science,* **1**(3), pp.87-92.

240. Simpson, J., Chalmers, D., Waller, A., Bird, Y., Quarrie, K., Gerrard, D., et al. (1994). *Tackling rugby injury: recommendations for reducing injury to rugby union players in New Zealand*. Otago, N.Z.; New Zealand: University of Otago. Injury Prevention Research Unit and Human Performance Centre.

241. Sinibaldi, K. Smith, D. (2007). Prevention of spinal injuries in rugby. *Strength and Conditioning Journal*, **29**(4), pp.1524-1602.

242. Snijders, C. Vleeming, A. Stoeckart, R. (1993). Transfer of lumbosacral load to the iliac bones and legs. Part 1: biomechanics of self-bracing of the sacroiliac joints and its significance for treatment and exercise. *Clinical Biomechanics*, **8**, pp.285-294.

243. Sohl, P., & Bowling, A. (1990). Injuries to dancers : prevalence, treatment and prevention. *Patient Management,* **14**(9), pp.69-75;95.

244. Solomon, R., Micheli, L., Solomon, J., & Kelley, T. (1995). The cost of injuries in a professional ballet company:anatomy of a season. *Medical Problems of Performing Artists,* **10**(1), pp.3-10.

245. Solomon, R., Micheli, L., Solomon, J., & Kelley, T. (1996). The cost of injuries in a professional ballet company: a three year prospective. *Medical problems of performing artists,* **11**(3), pp.67-74.

246. Solomon, R., Solomon, J., Micheli, J., & McGray, E. (1999). The cost of injuires in a professional ballet company: A five-year study. *Medical Problems of Performing Artists,* **14**(4), pp.164-169.

247. Sommer, H. M. and Vallentyne, S. W. (1995). Effect of foot posture on the incidence of medial tibial stress syndrome / Effet de la posture du pied sur la frequence d

' apparition du syndrome de stress median tibial. *Medicine & Science in Sports & Exercise*, **27**(6), pp.800-804.

248. Southwick, H. Cassella, M. (2002). Boston Ballet student screening clinic: an aid to injury prevention. *Orthopaedic Physical Therapy Practice*, **14**(2), pp.14-16.

249. Stasinopoulos, D. (2004). Comparison of three preventive methods in order to reduce the incidence of ankle inversion sprains among female volleyball players. *British Journal of Sports Medicine*, **38**(2), pp.182-185.

250. Stretanski, M. (2002). Classical ballet: the full contact sport. *American Journal of Physical Medicine Rehabilitation*, **81**, pp.392-393.

251. Stroup, D. Berlin, J. Morton, S. Olkin, S. Williamson, G. Rennie, D. Moher, D. Becker, B. Sipe, T, Thacker, S. (2000). Meta-analysis of observational studies in epidemiology. Journal of the American Medical Association **19**, 283, pp15208-2012

252. Teitz, C. C., & Kilcoyne, R. F. (1998). Premature osteoarthrosis in professional dancers. *Clinical Journal Of Sport Medicine: Official Journal Of The Canadian Academy Of Sport Medicine,* **8**(4), pp.255-259.

253. Tenforde, A. Shull, P. Fredericson, M. (2012). Neuromuscular prehabilitation to prevent osteoarthritis after traumatic joint injury. *Physical Medicine and Rehabilitation.* **4:**s141-s144

254. Teyhen, D. Shaffer, S. Lorenson, C. Halfpap, J. Donofry, D. Walker,M . Dugan, J. Childs, J (2012). The functional movement screen: a reliability study. *Journal of Orthopeadics and Sports Physical Therapy*, **42**(6):530-540

255. Trees AH, Howe TE, Grant M, Gray HG. Exercise for treating anterior cruciate ligament injuries in combination with collateral ligament and meniscal damage of the knee in adults. *Cochrane Database of Systematic Reviews* 2007, Issue 3. Art. No.: CD005961. DOI: 10.1002/14651858.CD005961.pub2.

256. Trees AH, Howe TE, Dixon J, White L. Exercise for treating isolated anterior cruciate ligament injuries in adults. *Cochrane Database of Systematic Reviews* 2005, Issue **4**. Art. No.: CD005316. DOI: 10.1002/14651858.CD005316.pub2.

257. Trojian, T. McKeag, D. (2006)Single leg balance test to identify risk of ankle sprains. *British Journal of Sports Medicine*, **40**(7), pp.610-613.

258. Turner, A. P., Barlow, J. H., & Heathcote-Elliott, C. (2000). Long term health impact of playing professional football in the United Kingdom. *British Journal of Sports Medicine,* **34**(5), pp.332-337.

259. Twitchett E, Angioi M, Koutedakis Y, et. al. (2010). The demands of a working day among female professional ballet dancers. *Journal of Dance Medicine and Science*, **4**, pp.127-132.

260. Twitchett, E., Angioi, M., Koutedakis, Y., & Wyon, M. (2009). Video Analysis of Classical Ballet Performance. *Journal of Dance Medicine and Science,* **13**(4), pp.124-128.

261. Ureña, Carla Alicia, "Skill Acquisition in Ballet Dancers: The Relationship between Deliberate Practice and Expertise" (2004). Electronic Theses, Treatises and Dissertations. Paper 1452. http://diginole.lib.fsu.edu/etd/1452

262. van Dijk, C. Lim, . Poortman, A. Strubbe, E. & Marti, R. (1995). Degenerative joint disease in female ballet dancers. *The American Journal of Sports Medicine*, **23**(3),pp:295-3000

263. van Mechelen, W., Hlobil, H., & Kemper, H. C. G. (1992). Incidence, severity, aetiology and prevention of sports injuries : a review of concepts (Incidence, gravite, etiologie et prevention des traumatismes sportifs : une revue de concepts). *Sports Medicine,* **14**(2), pp.82-99.

264. Vanekova, M. Ost'adal, M. Seidl, Z. Podskubka, A. Obenberger, J. Vitak, I. Danes, J. (2001). Jumpers knee: diagnosis, surgical treatment and return to high level performance within three months. *European Journal of Sports Trauma and Related Research*, **23**, pp.179-182.

265. Vann, M. A., & Manoli, A. (2010). Medial Ankle Impingement Syndrome in Female Gymnasts. *Operative Techniques in Sports Medicine,* **18**(1), pp.50-52.

266. Van Zile, J. (1986) What is dance? Implications for dance notation. *Dance Research Journal*, **17**(2), pp.41-47.

267. Verhagen, E. Bay, K. (2010). Optimising ankle sprain prevention: a critical review and practical appraisal of the literature. *British Journal of Sports Medicine.* **44**:1082-1088

268. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative (2008) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)statement: guidelines for reporting observational studies. *J Clin Epidemiol.* **61**(4): pp 344-9. PMID: 18313558

269. Waller, A. E., Feehan, M., Marshall, S. W., & Chalmers, D. J. (1994). The New Zealand Rugby Injury and Performance Project: I. Design and methodology of a prospective follow-up study. *British Journal Of Sports Medicine,* **28**(4), pp.223-228.

270. Wainner, R. S., Whitman, J. M., Cleland, J. A., & Flynn, T. W. (2007). Regional interdependence: a musculoskeletal examination model whose time has come. *The Journal Of Orthopaedic And Sports Physical Therapy,* **37**(11), pp.658-660.

271. Warren, M. Brooks-Gunn, J. Hamilton, L. Warren, L. Hamilton, W. (1986). Scoliosis and fractures in young ballet dancers. Relation to delayed menarche and secondary amenorrhea. *New England Journal of Medicine,* 314(21), pp.1348-1353.

272. Waterman, H. Tillen, D. Dickson, R. de Koning, K. (2001).Action research: a systematic review and guidance for assessment. *Health Technology Assessment*, vol **5** no 23.

273. Weatherburn (1962). *A first course in mathematical statistics.* Cambridge University Press.

274. Wheeler, L. P. (1987). Common musculoskeletal dance injuries. *Chiropractic Sports Medicine,* **1**(1), pp:17-23

275. Wiesler, E. R., Hunter, M., Martin, D., Curl, W. W. and Hoen, H. (1996) Ankle flexibility and injury patterns in dancers. *American Journal of Sports Medicine*, **24**(6), pp.754-757.

276. Willson, J. Dougherty, C. Ireland, M. Davis, I (2005). Core stability and its relationship to lower extremity function and injury. *Journal American Acadamy Orthopeadic Surgery*, **13**(5), pp.316-25.

277. Wingfield, K. Matheson, G. Meeuwisse, W. (2004). Preparticipation evaluation: an evidence-based review. *Clinical Journal of Sports Medicine,* **14**, pp.109-122.

278. Wolman R, Wyon MA, Koutedakis Y, Nevill, AM. Eastell, R. Allen, N. (2013) Vitamin D status in professional ballet dancers: Winter vs. summer. *J Sci Med Sport* **6**(5): pp 388-91

279. Wyon, M., Head, A., Sharp, N. C. C., Redding, E., & Abt, G. (2004). Oxygen Uptake During Modern Dance Class, Rehearsal, and Performance. *Journal of Strength and Conditioning Research,* **18**(3), pp.646-649.

280. Yates, B. and White, S. (2004). The incidence and risk factors in the development of medial tibial stress syndrome among naval recruits. *American Journal of Sports Medicine*, **32**(3), pp.772-780.

281. Yoo, J. Lim, B. Ha, M. Lee, S. Oh, S. Lee, Y. Kim, J. (2010). A meta-analysis of the effect of neuromuscular training on the prevention of the anterior cruciate ligament injury in female athletes. *Knee Surg Sports Traumatol Athrosc*. **18**:824-830

282. Zech, A. Hubscher, M. Vogt, L. Banzer, W. Hansel, F. Pfeifer, K. (2010) .Balance training for neuromuscular control and performance enhancement: a systematic review. *Journal of Athletic training*. **45**(40:392-403

283. Zöch, C., Fialka-Moser, V. and Quittan, M. (2003). Rehabilitation of ligamentous ankle injuries: a review of recent studies. *British Journal of Sports Medicine*, **37**(4), pp.291-295.

Chapter 10: Appendices

Appendix 1: Ethics approval letter

UNIVERSITY OF
WOLVERHAMPTON
School of Sport, Performing Arts and Leisure

Dean: John Pymm BA MEd MPhil ILTM AIEA

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18th June 2010

Nick Allen,
School of Sport, Performing Arts & Leisure,
University of Wolverhampton,
Gorway Road,
Walsall,
WS1 3BD

Dear Nick,

RE: Epidemiology of Dance Injuries

This letter is to confirm that the above project was considered by the Ethics Committee of The School of Sport, Performing Arts & Leisure, University of Wolverhampton on 16/06/2010. I can confirm that after consideration the Committee granted ethical approval for the project.

Yours sincerely

Karen Bill

Karen Bill
Associate Dean (Research)
School of Sport, Performing Arts & Leisure

Vice-Chancellor
Professor Caroline Gipps MSc PhD AcSS FRSA

Appendix 2: Ethics information sheet: Study 1

School of Sport, Performing Arts and Leisure
University of Wolverhampton

Primary researchers: Nick Allen

A prospective study examining the incidence and aetiology of injuries in professional dancers

Background: Artistic athletes such as dancers are presently exposed to extreme physical demands and are subject to risk of injury with injury rates varying from 0.62-5.6 injuries/1000hrs. However, increased injury rates and their deleterious effects have been linked to short dance careers with tremendous financial costs to both dancers and dance companies. Understanding injury risk, through establishing the extent of the injury, along with potential intrinsic risk factors are key elements in this models as effective interventions can be planned and tested. In dance medicine literature, however, there is a lack of well-designed epidemiological studies where injury incidence and aetiology can be compared with previous research in dance or sport data.

Purpose: The aim of this study was to use a prospective injury surveillance programme through a novel dance medicine approach to evaluate injury incidence in a cohort of professional dancers.

Methods: You will be asked to allow your anonymised screening, injury and treatment data to be used for research purposes. This information is collected during the screening and treatment at the Jerwood Centre, BRB and your personal information will be replaced by a unique reference code that only Nick Allen (Clinical Director) will know.

Confidentiality: All data will be strictly confidential and in line with the code of conduct of the British Association of Sport and Exercise Sciences. Your data will be stored in a locked cabinet at the University of Wolverhampton and eventually destroyed. All data will be recorded without names; a code will be created to record the scores. The only people with access to the anonymised data will be the researchers.

You are free to withdraw from participating in this research and withdraw use of your data at any time without any negative pressure or consequences.

Please place a cross box to confirm that:

1. you have read and understand the information sheet for the above study and have had opportunity to ask questions ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐

3. You have completed a PAR-Q and have been free from injury during the past 3 months. ☐

Name of participant:____

Signature of participant:____

Date

If you require further information, please contact: Matthew Wyon (University of Wolverhampton) **Telephone: 01902 323144 (9am-5pm), or email m.wyon@wlv.ac.uk**

Appendix 3: Ethics information sheet: Study 2

School of Sport, Performing Arts and Leisure
University of Wolverhampton

Primary researchers: Nick Allen

A prospective study examining the effect of individualised interventions on injury incidence in professional dancers

Background: Artistic athletes such as dancers are presently exposed to extreme physical demands and are subject to risk of injury with injury rates varying from 0.62-5.6 injuries/1000hrs. However, increased injury rates and their deleterious effects have been linked to short dance careers with tremendous financial costs to both dancers and dance companies. Understanding injury risk, through establishing the extent of the injury, along with potential intrinsic risk factors are key elements in this models as effective interventions can be planned and tested. The use of previous injury history and pre-participation screening data regarding musculoskeletal risk factors has been confirmed by the sports medicine literature[19]. In dance medicine literature, however, there is a lack of well-designed epidemiological studies where interventional strategies for injury prevention can be effectively evaluated.

Purpose: The aim of this study was to use a prospective injury surveillance programme through a novel dance medicine approach to evaluate the effect of an interventional programme on injury incidence in a cohort of professional dancers.

Methods: You will be asked to allow your anonymised screening, injury and treatment data to be used for research purposes. This information is collected during the screening and treatment at the Jerwood Centre, BRB and your personal information will be replaced by a unique reference code that only Nick Allen (Clinical Director) will know.

Confidentiality: All data will be strictly confidential and in line with the code of conduct of the British Association of Sport and Exercise Sciences. Your data will be stored in a locked cabinet at the University of Wolverhampton and eventually destroyed. All data will be recorded without names; a code will be created to record the scores. The only people with access to the anonymised data will be the researchers.

You are free to withdraw from participating in this research and withdraw use of your data at any time without any negative pressure or consequences.

Please place a cross box to confirm that:

1. You have read and understand the information sheet for the above study and have had opportunity to ask questions ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐

3. You have completed a PAR-Q and have been free from injury during the past 3 months. ☐

Name of participant:____

Signature of participant:____

Date

If you require further information, please contact: Matthew Wyon (University of Wolverhampton) **Telephone: 01902 323144 (9am-5pm), or email m.wyon@wlv.ac.uk**

Appendix 4: Injury Audit Form

Data Heading	**Category examples**
Name	
Gender	Male / Female
Position	Principal / Soloist /1^{st} Artist / Artist
Assessment Date	
Date of Injury	
Time Exercising that Day	
Intensity	1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 10
Recovery Strategy Employed	Stretch / Compression garment / Ice Bath etc.
Last Meal	
Hydration	No / Water / Isotonic / Other
Activity	Rehearsal / Performance / Class /Fitness / Other etc
Show	
Occurrence	First-Episode / Recurrence / Exacerbation
Able to Continue	Yes / No
If not, Reason	Forced / Precautionary
Movement Performed	Arabesque/Small Jumps/ Middle Jumps/Lifting etc
Where	Studio / Stage / Gym / Pool / Other
Footwear	Ballet / Barefoot / Jazz /Pointe /Trainers /Other. etc
Body Part	Head / Trunk / Upper Limb / Lower Limb
Specific Area Injured	

Present Stage of Healing	Acute (3 Weeks) / Chronic (>10 weeks) Sub-acute (3-8 weeks) / Acute-on-Chronic
Type	Overuse / Traumatic
Nature	Extrinsic / Intrinsic / Other
Injury	
Mechanism	Accelerated Environmental Conditions / Muscle Imbalance / etc.
Severity (count in days from injury onset to return to full activity)	Transient (Return within 7 Days) / Mild (Return 7-28 Days) / Moderate (Return 29-84 Days) / Severe (Return after 84 Days)
Provisional Diagnosis	
Full Days Off (full restriction from dance related activity)	
Notes incl. Investigations	

Appendix 5: Functional Performance Screen

Scoring Sheet

Hand Dominance: Right

Leg Dominance: Right

TEST	RAW SC	FINAL	COMMENTS
SL STAND L 30sec eyes closed	2	2	Unable to control when foot drops into pronated posture. Increased int rot @femur when on Lt> Rt
SL STAND R 30sec eyes closed	3		
DEEP SQUAT	3	3	Increased trunk flexion. Lt hip retracts at ¾ squat
HURDLE ST. **L**	3	3	Some increased compensation in stance leg on right foot- mild hip hitch on Lt
HURDLE ST. **R**	3		
IN-LINE LUN. **L**	2	2	Increased give + Lt hip laterally> Rt- both challenged.
IN-LINE LUN. **R**	3		
SHO. MOB. **L**	5	5	
SHO. MOB. **R**	5		
ACTIVE IMP. **L**	-	-	Impingement cleared
ACTIVE IMP. **R**	-		
ASLR **L**	5	5	
ASLR **R**	5		
ASLR 6” with directional support	Lt	Lt	Equal Mens with manual pelvic stabilisation
TSPU		3	
ROT. STAB. **L**	3	3	
ROT. STAB. **R**	4		
FLX	-	-	Spinal flexion cleared
TOTAL **PERCENTAGE**		26 /45 57 %	

Comments
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Appendix 6: HIM example programme

Exercise and progression	*Description: session A (perform 3x week)*	***Progressive Overload*** *Reps per set*	Sets	Rest betw'n sets
1. Side lying Theraband hip extension	Lying on your right side, with your right leg slightly bent to support you, and your left leg placed in degrees of increasing flexion. Theraband secured level with body towards the head and looped around your left thigh. Ensure the band is taut enough that there is already significant resistance to your thigh straightening. Gradually extend your left leg and hold the contraction for 8-10 sec. Relax 1 sec. Slide your body further down away from the attached point of the band to increase the degree of flexion at your hip. Repeat ex. Progress one more time with further hip flex. Switch legs/side.	3-5/leg with 7 sec hold	2	3 sec between contract
2. Side lying Theraband hip external rotation	Side lying on right hip but with upper body twisted upwards, with your right leg slightly bent to support you, and your left leg placed in degree of flexion. Theraband attached level with hip higher than body, looped around heel, taut enough to pull heel towards ceiling gently. Gently pull heel in direction of floor and hold for 10sec. Repeat	3-5/leg with 7 sec hold	2	3 sec between contract
3. Leg kick in prone	Lie on stomach (place legs off-center to left at start if uneven), legs extended, bend knee to 90°, lift thigh off floor, extend knee, return to start position. Alternate.	10 reps (slow)	2	30sec
4. Side lying Theraband abduction/hip draw with bent knees	Lying on side, both knees bent to 90°, hips at 90°. Draw point on lateral knee towards lateral hip while maintaining Theraband looped around knees (with a constant resistance- hips are just greater that pelvic width apart) Hold. Return under control.	10x10 sec hold	2	30sec
5. Single leg Theraband Romanian deadllift	Standing on left leg with hips flexed at 30-40° small bend at knee. Theraband looped between left foot and right hand (arm straight) under resistance. Return to upright posture. Once set is complete, change leg and hand. Progress to standing on balance mat	15-18/leg	2	30sec
6. Standing Theraband pull	Standing on one leg. Pull through Theraband with opposite arm, elbow straight from front to back passed hip, Progress to standing on balance mat	10/leg	2	30sec
7. Standing single leg hitch	Standing with left leg on step, allowing right leg to be place off step unsupported. Maintain hip level and draw right hip up so that the right foot is just higher than step height. Return under control to below step level. After set swap legs	20/leg	2	30sec

Exercise and progression	*Description: session B (perform 3x week)*	***Progressive Overload***		
		Reps per set	Sets	Rest betw'n sets
1. Side lying Theraband hip extension	Lying on your right side, with your right leg slightly bent to support you, and your left leg placed in degrees of increasing flexion. Theraband secured level with body towards the head and looped around your left thigh. Ensure the band is taut enough that there is already significant resistance to your thigh straightening. Gradually extend your left leg and hold the contraction for 8-10 sec. Relax 1 sec. Slide your body further down away from the attached point of the band to increase the degree of flexion at your hip. Repeat ex. Progress one more time with further hip flex. Switch legs/side.	3-5/leg with 8-10sec hold	2	3 sec between contract
2. Side lying Theraband hip external rotation	Side lying on right hip but with upper body twisted upwards, with your right leg slightly bent to support you, and your left leg placed in degree of flexion. Theraband attached level with hip higher than body, looped around heel, taut enough to pull heel towards ceiling gently. Gently pull heel in direction of floor and hold for 10sec. Repeat	3-5/leg with 8-10sec hold	2	3 sec between contract
3. Leg kick in prone	Lie on stomach (place legs off-center to left at start if uneven), legs extended, bend knee to 90°, lift thigh off floor, extend knee, return to start position. Alternate.	10 reps (slow)	2	30sec
4. Side lying abduction with straight leg and turn out	Lying on side, underside leg bent at knee to 90°, depending on ability hip either bent up at 30-45°, or advanced with hip straight. Top leg is abducted 15-20°, extended at hip 15° and laterally rotated, while maintaining lumbar spine neutral. Return under control	6/leg with 6-10 sec hold	2	30sec
5. Prone Swiss Ball glut/ham extension	Lying on front with hips supported by Swiss Ball, hands on floor with elbows slightly bent. Raise both legs and trunk to just passed neutral with slight extension of elbows	8-12	2	30sec
6. Single leg forward reach	Standing on left leg, small bend at knee. Bend at trunk/hips and reach as far forward as possible holding a med ball with a 1sec pause, then return to upright posture. Once set is complete, change leg. Progress to standing on balance mat	9 each leg	2	30sec
7. Standing single leg hitch	Standing with left leg on step, allowing right leg to be place off step unsupported. Maintain hip level and draw right hip up so that the right foot is just higher than step height. Return under control to below step level. After set swap legs	20/leg	2	30sec